UNCLASSIFIED

AD NUMBER
AD914123
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies only; Test and Evaluation; OCT 1973. Other requests shall be referred to Air Force Armament Laboratory, Attn: DLJA, Eglin AFB, FL 32542.**
AUTHORITY
AFAL ltr, 30 Oct 1975

THIS PAGE IS UNCLASSIFIED

AEDC-TR-73-174
AFATL-TR-73-207
Cy. 2

NOV 6 1973

SEPARATION CHARACTERISTICS OF THE CTU-1/A, FINNED BLU-1C/B, AND CBU-24B/B STORES FROM THE A-7D AIRCRAFT AT MACH NUMBERS 0.42 TO 1.05

J. B. Carman, Jr.

ARO, Inc.

October 1973

This document ... public release ... Per TAB 16-3, 30 Jan. 1976

Distribution limited to U. S. Government agencies only; this report contains information on test and evaluation of military hardware: October 1973; other requests for this document must be referred to Air Force Armament Laboratory (DLJA), Eglin AFB, Florida 32542.

PROPULSION WIND TUNNEL FACILITY
ARNOLD ENGINEERING DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
ARNOLD AIR FORCE STATION, TENNESSEE

NOTICES

SEPARATION CHARACTERISTICS OF THE CTU-1/A, FINNED BLU-1C/B, AND CBU-24B/B STORES FROM THE A-7D AIRCRAFT AT MACH NUMBERS 0.42 TO 1.05

J. B. Carman, Jr.
ARO, Inc.

FOREWORD

The work reported herein was conducted by the Arnold Engineering Development Center (AEDC) under sponsorship of the Air Force Armament Laboratory (AFATL/DLJA), Air Force Systems Command (AFSC), under Program Element 27121F, System 337A.

The test results presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the AEDC, AFSC, Arnold Air Force Station, Tennessee. The tests were conducted on July 25 and 26, 1973, under ARO Project No. PA344. The manuscript was submitted for publication on August 22, 1973.

This technical report has been reviewed and is approved.

L. R. KISSLING
Lt Colonel, USAF
Chief Air Force Test Director, PWT
Directorate of Test

FRANK J. PASSARELLO
Colonel, USAF
Director of Test

ABSTRACT

Wind tunnel tests were conducted using 0.05-scale models to study the separation characteristics of the CTU-1/A, finned BLU-1C/B, and CBU-24B/B stores from the A-7D aircraft. Separation trajectories of the CTU-1/A store were initiated from the left and right wing outboard pylons while separation trajectories of the finned BLU-1C/B and CBU-24B/B munitions were initiated from a multiple ejection rack on the left and right wing center pylons. Data were obtained at Mach numbers 0.42 to 1.05 at simulated altitudes of 500 to 8000 ft. Other simulated flight variables included store weight and center-of-gravity position, dive angle, and ejector force.

CONTENTS

APPENDIXES

NOMENCLATURE

BL	Aircraft buttock line from plane of symmetry, in., model scale
b	Store reference dimension, ft, full scale
C_A	Store axial-force coefficient, axial force/$q_\infty S$
C_ℓ	Store rolling-moment coefficient, rolling moment/$q_\infty Sb$
C_{ℓ_p}	Store roll-damping derivative, $dC_\ell/d(pb/2V_\infty)$
C_m	Store pitching-moment coefficient, referenced to the store cg, pitching moment/$q_\infty Sb$
C_{m_q}	Store pitch-damping derivative, $dC_m/d(qb/2V_\infty)$
C_N	Store normal-force coefficient, normal force/$q_\infty S$
C_n	Store yawing-moment coefficient, referenced to the store cg, yawing moment/$q_\infty Sb$
C_{n_r}	Store yaw-damping derivative, $dC_n/d(rb/2V_\infty)$
C_Y	Store side-force coefficient, side force/$q_\infty S$
F_{Z_1}	Forward ejector force, lb
F_{Z_2}	Aft ejector force, lb
H	Pressure altitude, ft

I_{xx}	Full-scale moment of inertia about the store X_B axis, slug-ft^2
I_{yy}	Full-scale moment of inertia about the store Y_B axis, slug-ft^2
I_{zz}	Full-scale moment of inertia about the store Z_B axis, slug-ft^2
MS	Aircraft fuselage station, in., model scale
M_∞	Free-stream Mach number
$\overline{m}$	Full-scale store mass, slugs
p	Store angular velocity about the X_B axis, radians/sec
p_∞	Free-stream static pressure, psfa
q	Store angular velocity about the Y_B axis, radians/sec
q_∞	Free-stream dynamic pressure, psf
r	Store angular velocity about the Z_B axis, radians/sec
S	Store reference area, ft^2, full scale
t	Real trajectory time from initiation of trajectory, sec
V_∞	Free-stream velocity, ft/sec
WL	Aircraft waterline from reference horizontal plane, in., model scale
X	Separation distance of the store cg parallel to the flight axis system X_F direction, ft, full scale measured from the prelaunch position
X_{cg}	Full-scale cg location, ft, from nose of store
X_{L_1}	Forward ejector location relative to the store cg, positive forward of store cg, ft, full scale
X_{L_2}	Aft ejector piston location relative to the store cg, positive forward of store cg, ft, full scale
Y	Separation distance of the store cg parallel to the flight axis system Y_F direction, ft, full scale measured from the prelaunch position
Z	Separation distance of the store cg parallel to the flight-axis system Z_F direction, ft, full scale measured from the prelaunch position

α Parent-aircraft model angle of attack relative to the free-stream velocity vector, deg

θ Angle between the store longitudinal axis and its projection in the X_F-Y_F plane, positive when store nose is raised as seen by pilot, deg

γ Simulated parent-aircraft dive angle, angle between the flight direction and the earth horizontal, deg, positive for decreasing altitude

ψ Angle between the projection of the store longitudinal axis in the X_F-Y_F plane and the X_F axis, positive when the store nose is to the right as seen by the pilot, deg

ϕ Angle between the projection of the store lateral axis in the Y_F-Z_F plane and the Y_F axis, positive for clockwise rotation when looking upstream, deg

FLIGHT-AXIS SYSTEM COORDINATES

Directions

X_F Parallel to the free-stream wind vector, positive direction is forward as seen by the pilot

Y_F Perpendicular to the X_F and Z_F directions, positive direction is to the right as seen by the pilot

Z_F In the aircraft plane of symmetry, perpendicular to the free-stream wind vector, positive direction is downward

The flight-axis system origin is coincident with the aircraft cg and remains fixed with respect to the parent aircraft during store separation. The X_F, Y_F, and Z_F coordinate axes do not rotate with respect to the initial flight direction and attitude.

STORE BODY-AXIS SYSTEM COORDINATES

Directions

X_B Parallel to the store longitudinal axis, positive direction is upstream in the prelaunch position

Y_B Perpendicular to the store longitudinal axis, and parallel to the flight-axis system X_F-Y_F plane when the store is at zero roll angle, positive direction is to the right looking upstream when the store is at zero yaw and roll angles

Z_B Perpendicular to both the X_B and Y_B axes, positive direction is downward as seen by the pilot when the store is at zero pitch and roll angles.

The store body-axis system origin is coincident with the store cg and moves with the store during separation from the parent airplane. The X_B, Y_B, and Z_B coordinate axes rotate with the store in pitch, yaw, and roll so that mass moments of inertia about the three axes are not time-varying quantities.

SECTION I
INTRODUCTION

Wind tunnel store separation data for three stores launched from the A-7D aircraft were obtained using a six-degree-of-freedom captive trajectory store separation system (CTS). The test was conducted in the Aerodynamic Wind Tunnel (4T) of the Propulsion Wind Tunnel Facility (PWT) using 0.05-scale models of the A-7D aircraft and CTU-1/A, finned BLU-lC/B, and CBU-24B/B stores. The CTU-1/A separation trajectories were initiated from the left and right wing outboard pylons, whereas the separation trajectories of the finned BLU-1C/B and CBU-24B/B stores were initiated from a multiple ejection rack (MER) mounted on the left or right wing center pylon of the parent aircraft. Trajectory data were obtained at Mach numbers from 0.42 to 1.05 using simulated full-scale store weights and center-of-gravity locations. Other simulated flight variables included altitude and ejector force along with parent-aircraft angles of attack and dive angles.

SECTION II
APPARATUS

2.1 TEST FACILITY

The Aerodynamic Wind Tunnel (4T) is a closed-loop, continuous flow, variable density tunnel in which the Mach number can be varied from 0.1 to 1.3. At all Mach numbers, the stagnation pressure can be varied from 300 to 3700 psfa. The test section is 4 ft square and 12.5 ft long with perforated, variable porosity (0.5- to 10-percent open) walls. It is completely enclosed in a plenum chamber from which the air can be evacuated, allowing part of the tunnel airflow to be removed through the perforated walls of the test section.

For store separation testing, two separate and independent support systems are used to support the models. The parent-aircraft model is inverted in the test section and supported by an offset sting attached to the main pitch sector. The store model is supported by the CTS which extends down from the tunnel top wall and provides store movement (six degrees of freedom) independent of the parent-aircraft model. An isometric drawing of a typical store separation installation is shown in Fig. 1 (Appendix I).

Also shown in Fig. 1 is a block diagram of the computer control loop used during captive trajectory testing. The analog system and the digital computer work as an integrated unit and, utilizing required input information, control the store movement during a trajectory. Store positioning is accomplished by use of six individual d-c electric motors. Maximum translational travel of the CTS is ±15 in. from the tunnel centerline in the lateral and vertical directions and 36 in. in the axial direction. Maximum angular displacements are ±45 deg in pitch and yaw and ±360 deg in roll. A more complete description of the test facility can be found in Ref. 1. A schematic showing the test section details and the location of the models in the tunnel is shown in Fig. 2.

2.2 TEST ARTICLES

The basic dimensions of the 0.05-scale A-7D parent model are presented in Fig. 3. The parent model is geometrically similar to the full-scale airplane except that the horizontal tail is removed to minimize interference with CTS support movement. Details of the A-7 pylons and MER are shown in Figs. 4 and 5, respectively. The MER was aligned with the 30-in. suspension lug positions on the pylons. Details of the store models are given as follows: A-7 300-gal fuel tank (Fig. 6), full LAU-3/A (Fig. 7), CTU-1/A (Fig. 8), CBU-24B/B (Fig. 9), and finned BLU-1C/B (Fig. 10).

The numbering sequence and roll orientation of the stores for the MER stations are shown in Fig. 11. A typical tunnel installation photograph showing parent aircraft, store model, and CTS is shown in Fig. 12.

2.3 INSTRUMENTATION

A six-component, internal, strain-gage balance was used to obtain store aerodynamic force and moment data. Translational and angular positions of the store were obtained from CTS analog inputs while parent-model angle of attack was determined using an internal gravimetric, angular position indicator. The pylons and MER contained a touch wire system which enabled the store to be accurately positioned for launch. The system was also wired to automatically stop the CTS motion and give visual indication should the store or sting support make contact with any surface other than the touch wire.

SECTION III
TEST DESCRIPTION

3.1 TEST CONDITIONS

Separation trajectory data were obtained at Mach numbers from 0.42 to 1.05. Tunnel dynamic pressure was maintained near 500 psf at all Mach numbers and tunnel stagnation temperature was maintained near 100°F.

Tunnel conditions were held constant at the desired Mach number and stagnation pressure while data for each trajectory were obtained. The trajectories were terminated when the store or sting contacted the parent-aircraft model or when a CTS limit was reached.

3.2 TRAJECTORY DATA ACQUISITION

To obtain a trajectory, test conditions were established in the tunnel and the parent model was positioned at the desired angle of attack. The store model was then oriented to a position corresponding to the store carriage location. After the store was set at the desired initial position, operational control of the CTS was switched to the digital computer which controlled the store movement during the trajectory through commands to the CTS

analog system (see block diagram, Fig. 1). Data from the wind tunnel, consisting of measured model forces and moments, wind tunnel operating conditions, and CTS rig positions were input to the digital computer for use in the full-scale trajectory calculations.

The digital computer was programmed to solve the six-degree-of-freedom equations to calculate the angular and linear displacements of the store relative to the parent-aircraft pylon. In general, the program involves using the last two successive measured values of each static aerodynamic coefficient to predict the magnitude of the coefficients over the next time interval of the trajectory. These predicted values are used to calculate the new position and attitude of the store at the end of the time interval. The CTS is then commanded to move the store model to this new position and the aerodynamic loads are measured. If these new measurements agree with the predicted values, the process is continued over another time interval of the same magnitude. If the measured and predicted values do not agree within the desired precision, the calculation is repeated over a time interval one-half the previous value. This process is repeated until a complete trajectory has been obtained.

In applying the wind tunnel data to the calculations of the full-scale store trajectories, the measured forces and moments are reduced to coefficient form and then applied with proper full-scale store dimensions and flight dynamic pressure. Dynamic pressure was calculated using a flight velocity equal to the free-stream velocity component plus the components of store velocity relative to the aircraft, and a density corresponding to the simulated altitude.

The initial portion of each launch trajectory incorporated simulated ejector forces in addition to the measured aerodynamic forces acting on the store. The ejector force was considered to act perpendicular to the rack mounting surface. The ejector forces and locations along with other full-scale store parameters used in the trajectory calculations are listed in Table I (Appendix II).

3.3 CORRECTIONS

Balance, sting, and support deflections caused by the aerodynamic loads on the store models were accounted for in the data reduction program to calculate the true store-model angles and coordinates. Corrections were also made for model weight tares to calculate the net aerodynamic forces on the store model.

3.4 PRECISION OF DATA

The trajectory data are subject to error from several sources including tunnel conditions, balance measurements, extrapolation tolerances allowed in the predicted coefficients, computer inputs, and CTS positioning control. Maximum error in the CTS position control was ±0.05 in. for the translational settings and ±0.15 deg for the angular settings in pitch and yaw. Extrapolation tolerances were ±0.10 for the aerodynamic coefficients. The estimated uncertainty in setting Mach number was ±0.005 and uncertainty

in parent-model angle of attack was estimated to be ±0.1 deg. The maximum uncertainties in the full-scale position data caused by the balance inaccuracies are given below:

Store	t,sec	X,ft	Y,ft	Z,ft	θ,deg	ψ,deg	ϕ,deg
CTU-1/A	0.3	±0.14	±0.06	±0.05	±1.1	±1.4	±3.4
BLU-1C/B	0.3	±0.05	±0.02	±0.02	±0.3	±0.3	±1.1
CBU-24B/B	0.3	±0.04	±0.02	±0.02	±0.6	±0.8	±2.3

SECTION IV
RESULTS AND DISCUSSION

All trajectories obtained were for use in the determination of safe separation envelopes of the respective stores from the A-7D aircraft. No attempt will be made in this report to establish these envelopes or to qualify the store as safe or unsafe for aircraft separation. The trajectory data are presented as obtained from the wind tunnel along with comments regarding the aerodynamics of the store in the aircraft flow field.

Data taken during these tests consisted of ejector-separated trajectories simulating release from multiple carriage racks or from pylons alone. Data showing the linear displacements of stores relative to the carriage position and the angular displacements relative to the flight-axis system are presented as functions of full-scale trajectory time. Positive X, Y, and Z displacements (as seen by the pilot) are forward, to the right and down, respectively. Positive changes in θ, ψ, and ϕ (as seen by the pilot) are nose up, nose to the right, and clockwise, respectively. Table I lists the full-scale store parameters used in trajectory calculations, and Table II describes the aircraft load configuration nomenclature.

The launch trajectories for the CTU-1/A from the left and right wing outboard pylons are presented in Figs. 13 through 16. The "E" (Fig. 13), "E50" (Fig. 14), "E250" (Fig. 15), and "E500" (Fig. 16) series designations represent store weights of 215, 265, 465, and 715 lb, respectively. The notations "A" through "D" in the legend at the top of Figs. 14 through 16 indicate different store center-of-gravity positions. As the center-of-gravity location was moved aft, pitch increased negatively for constant store mass and ejector force as might be expected. Also shifting the larger ejector force from the forward foot (E-1 through E-4) to the aft foot (E-18 through E-21) and then eliminating the forward ejector force altogether (E-14 through E-17) resulted in increased pitch-up release characteristics for constant store mass and center-of-gravity position. Addition of the 300-gal fuel tank and full LAU-3/A stores on the inboard and center pylons, respectively (Configuration 1), did not significantly affect the store release characteristics.

Separation characteristics of the CBU-24B/B from a MER on the right wing center pylon are presented in Fig. 17. Pitch down of the store increased slightly with increasing Mach number, and the store moved forward from the point of release because of the steep dive angle. Increasing the ejector force by 450 lb resulted in only small changes in the trajectory at $M_\infty = 0.61$.

Shown in Fig. 18 are the launch trajectories for the finned BLU-1C/B from a MER on the left and right wing center pylons. The differences in store tail size (A and D2) did not seem to have any systematic influence on the trajectories from either the top or shoulder MER launch positions.

The aerodynamic coefficients measured with the store in the carriage position (Fig. 19) tended to verify the initial trajectory data of the BLU-1C/B store. The repeat data shown were taken with small alignment changes of the dummy stores and a slight adjustment in the store carriage position. Although small changes in data levels were noted, the shapes of the curves were similar.

REFERENCES

1. Test Facilities Handbook (Ninth Edition). "Propulsion Wind Tunnel Facility, Vol. 4." Arnold Engineering Development Center, July 1971.

2. Christopher, J. P. and Carleton, W. E. "Captive-Trajectory Store-Separation System of the AEDC-PWT 4-Foot Transonic Tunnel." AEDC-TR-68-200 (AD839743), September 1968.

APPENDIXES

I. ILLUSTRATIONS

II. TABLES

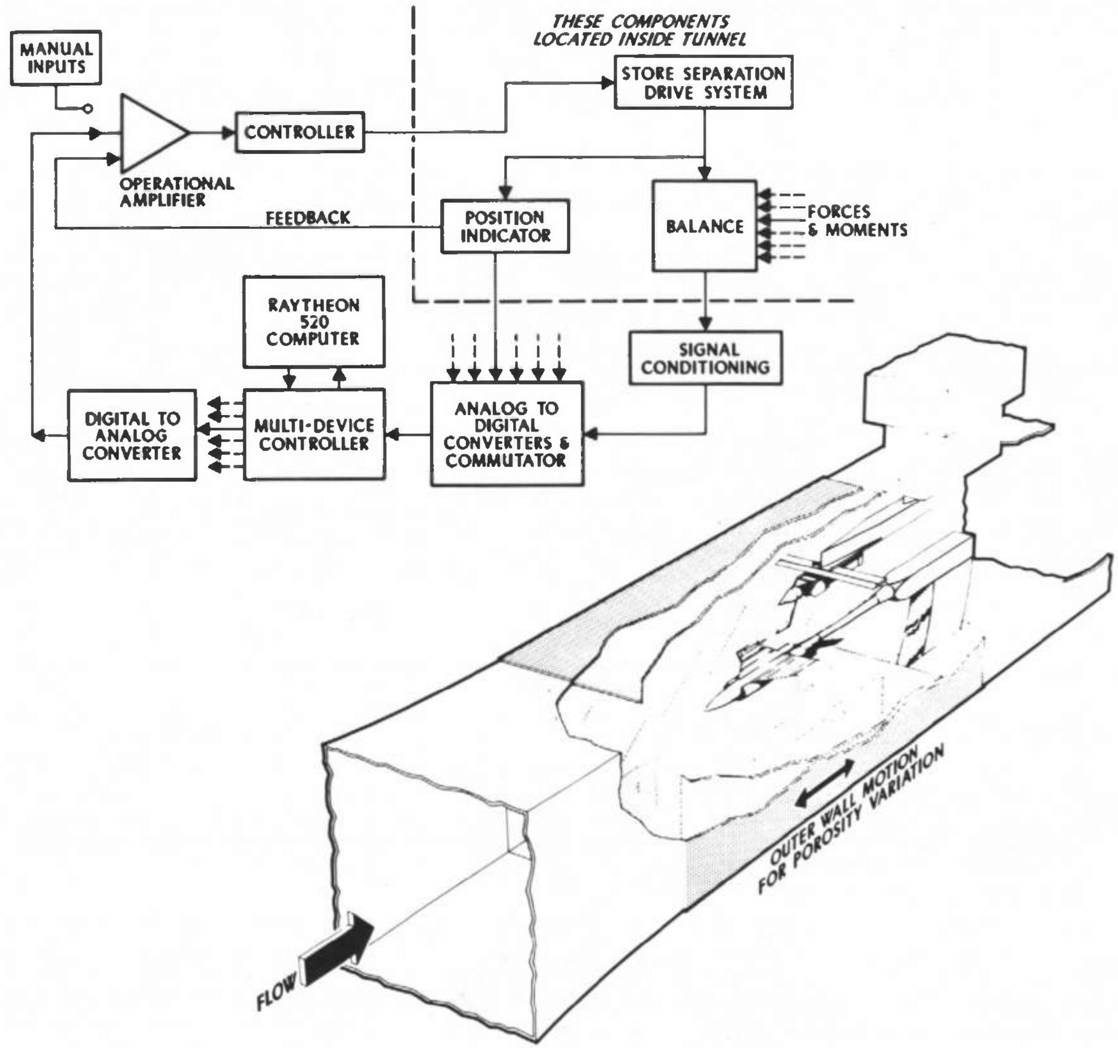


Fig. 1 Isometric Drawing of a Typical Store Separation Installation and a Block Diagram of the Computer Control Loop

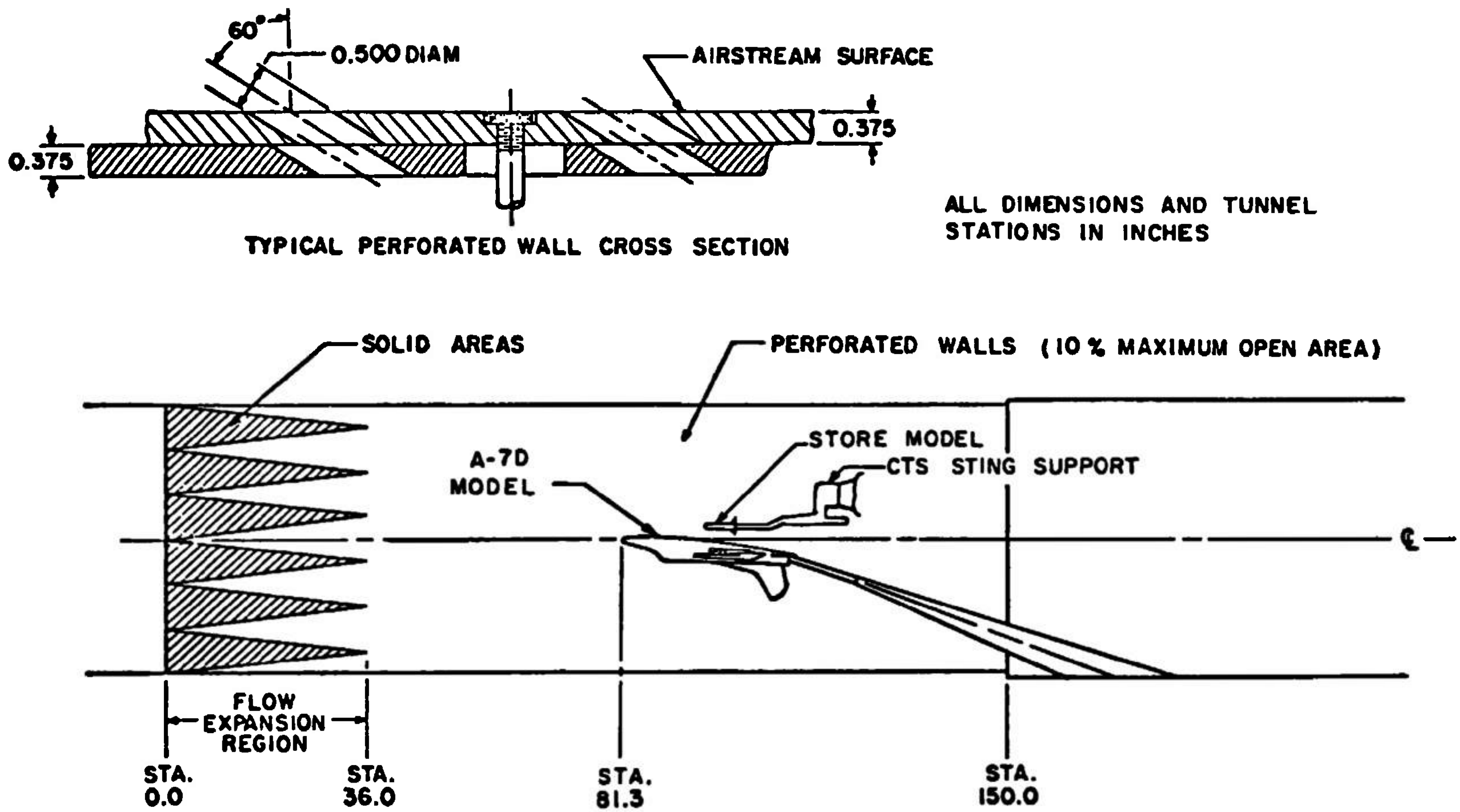


Fig. 2 Schematic of the Tunnel Test Section Showing Model Location

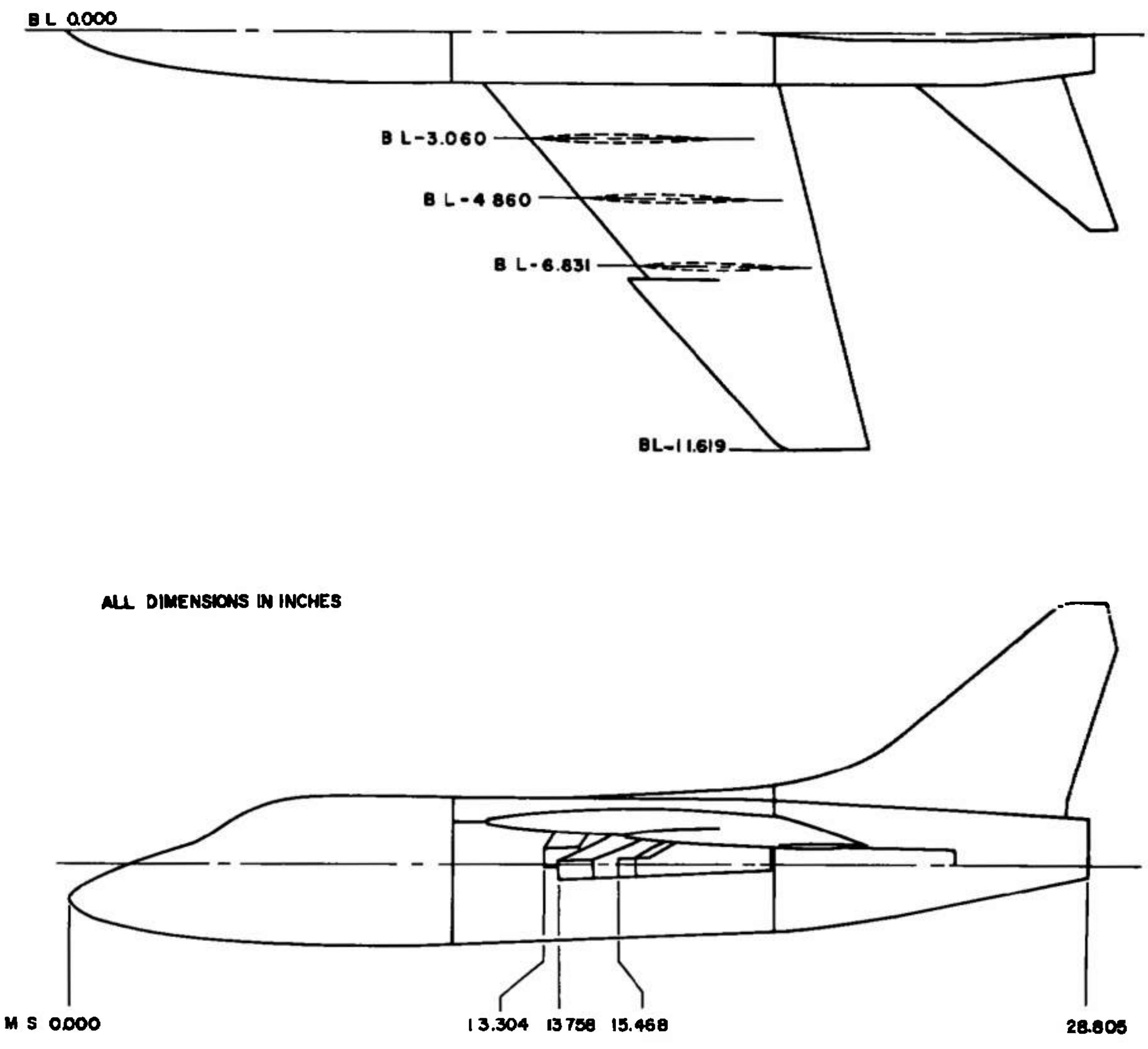
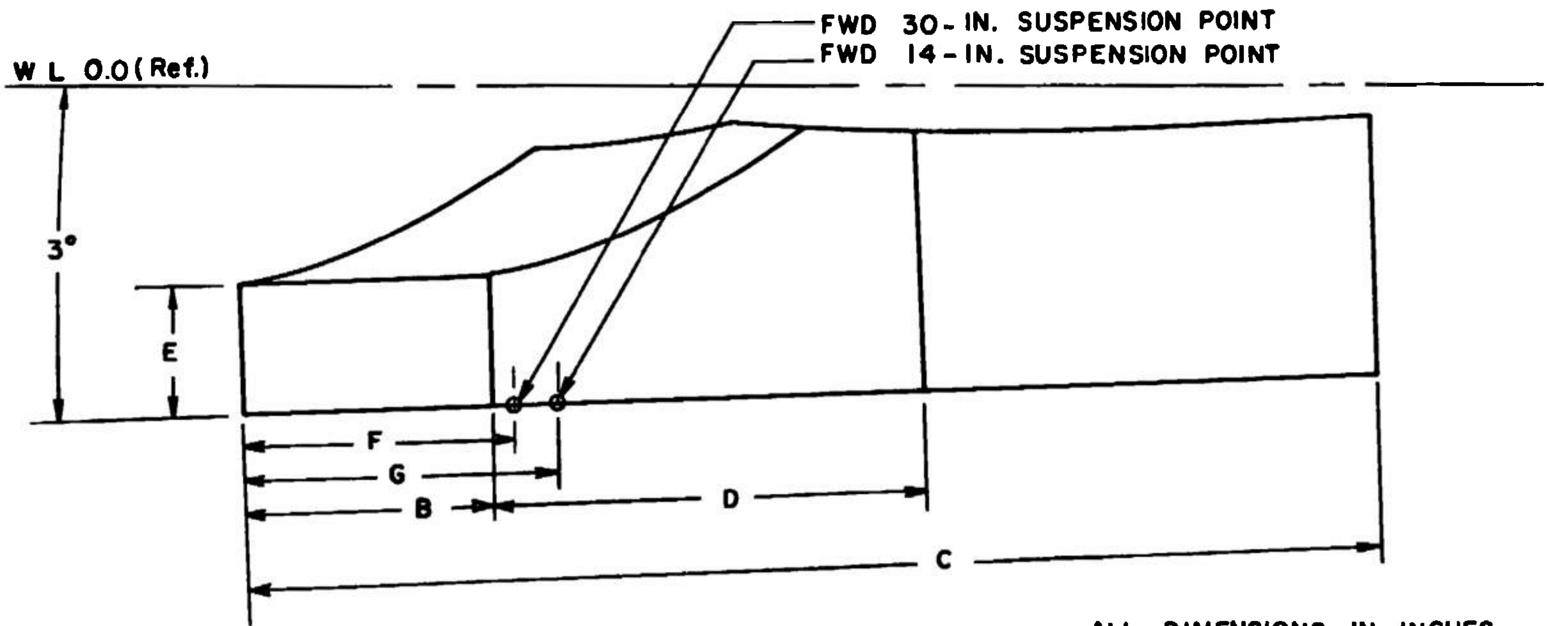


Fig. 3 Sketch of the A-7D Parent-Aircraft Model



ALL DIMENSIONS IN INCHES

	INBOARD	CENTER	OUTBOARD
B	1.030	1.030	0.515
C	4.580	4.850	4.437
D	1.630	1.905	2.008
E	0.575	0.575	0.513
F	0.950	0.950	0.750
G	1.350	1.350	1.150

Fig. 4 Details of the A-7 Pylon Models

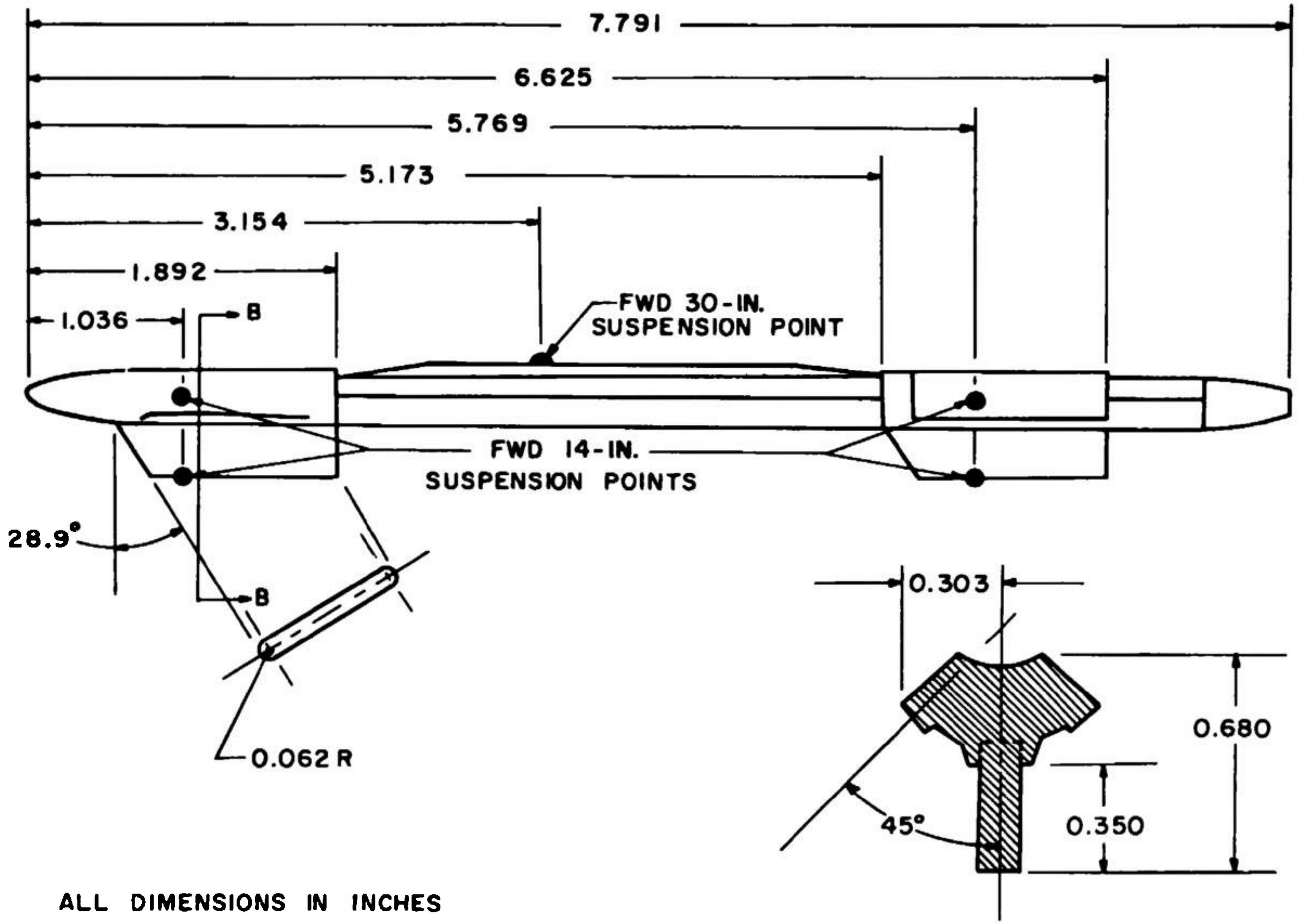
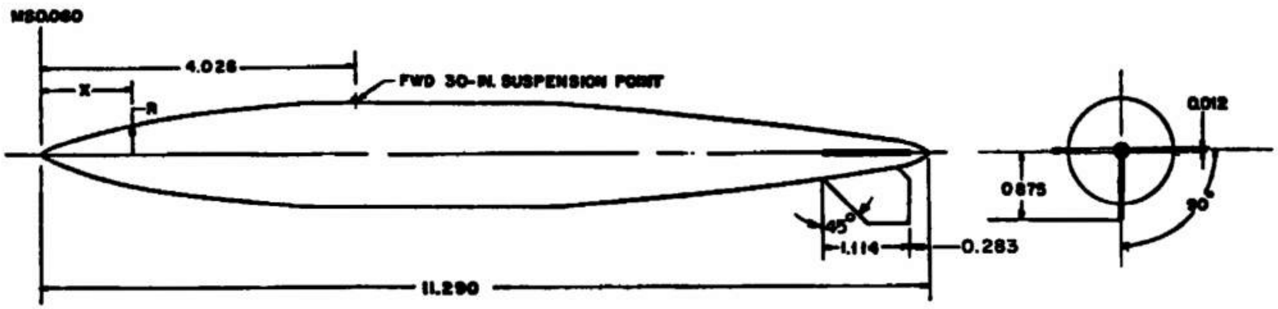


Fig. 5 Details of the A-7 MER Model

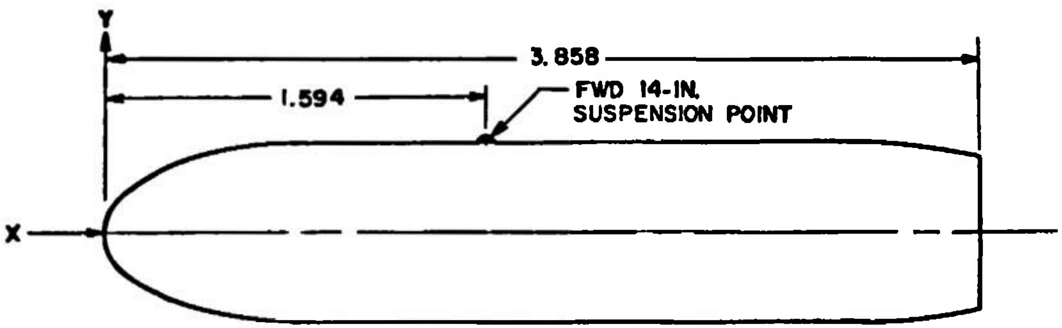
ORDINATES

MODEL STA "X"	RADIUS "R"	MODEL STA "X"	RADIUS "R"
0.000	0.0000	2.250	0.5531
0.060	0.0000	2.500	0.5777
0.100	0.0511	2.750	0.5989
0.150	0.0751		CONSTANT SLOPE
0.200	0.0981	3.450	0.6625
0.250	0.1203		CONSTANT DIAM
0.300	0.1415	6.638	0.6625
0.350	0.1619		CONSTANT SLOPE
0.400	0.1815	7.713	0.5680
0.450	0.2003	7.763	0.5637
0.500	0.2183	8.013	0.5409
0.550	0.2355	8.263	0.5162
0.600	0.2521	8.513	0.4899
0.650	0.2680	8.763	0.4620
0.700	0.2833	9.013	0.4327
0.750	0.2979	9.113	0.4208
0.800	0.3119		CONSTANT SLOPE
0.850	0.3253	10.900	0.1815
0.900	0.3383	10.950	0.1733
1.000	0.3625	11.000	0.1646
1.250	0.4153	11.100	0.1441
1.500	0.4587	11.200	0.1170
1.750	0.4950	11.300	0.0725
2.000	0.5260	11.350	0.0000



ALL DIMENSIONS AND MODEL STATIONS IN INCHES

Fig. 6 Details of the A-7 300-gal Fuel Tank Model

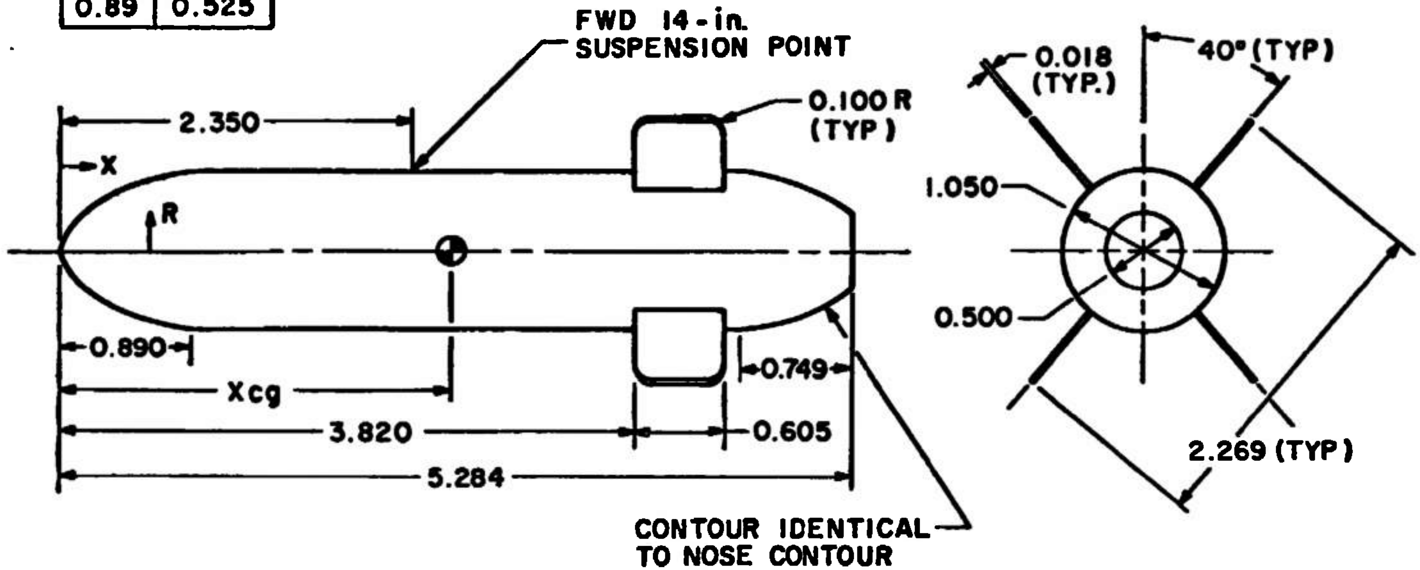


X	Y
0.000	0.000
0.100	0.182
0.200	0.249
0.300	0.296
0.400	0.333
0.500	0.359
0.600	0.376
0.700	0.386
0.800	0.391
0.900	0.393
3.450	0.393
3.550	0.391
3.650	0.385
3.750	0.373
3.858	0.358

ALL DIMENSIONS IN INCHES

Fig. 7 Details of the Full LAU-3/A Model

X, in.	R, in.
0	0
0.09	0.175
0.19	0.260
0.29	0.315
0.39	0.365
0.49	0.410
0.59	0.445
0.69	0.480
0.79	0.505
0.89	0.525



ALL DIMENSION IN INCHES

Fig. 8 Details of the CTU-1/A Model

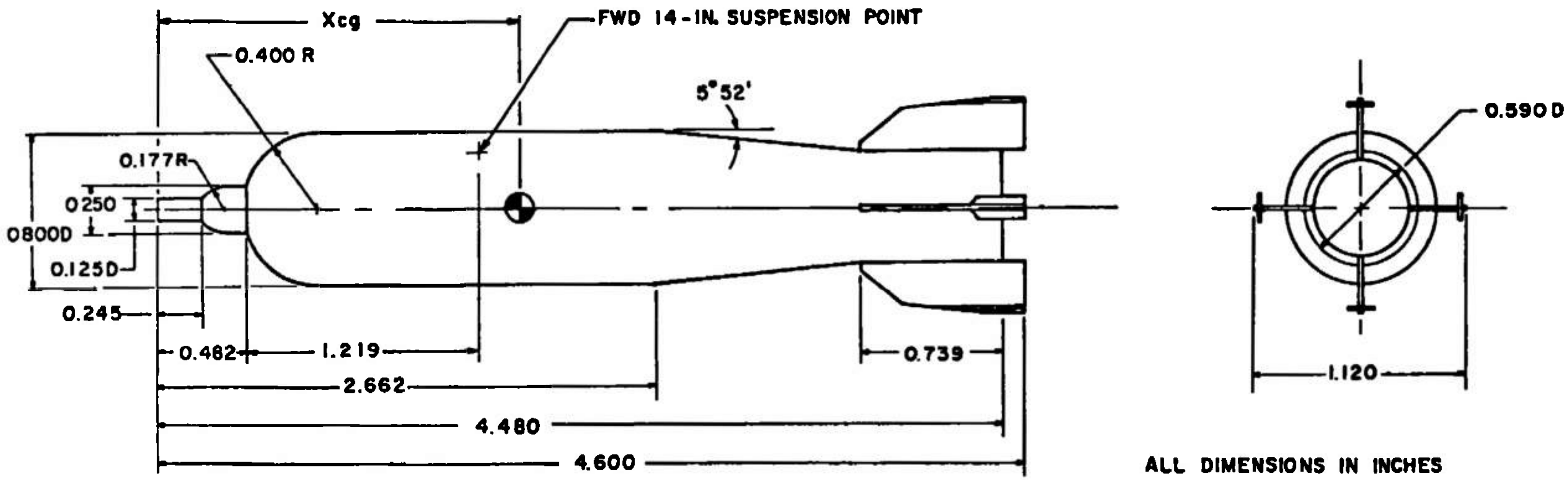
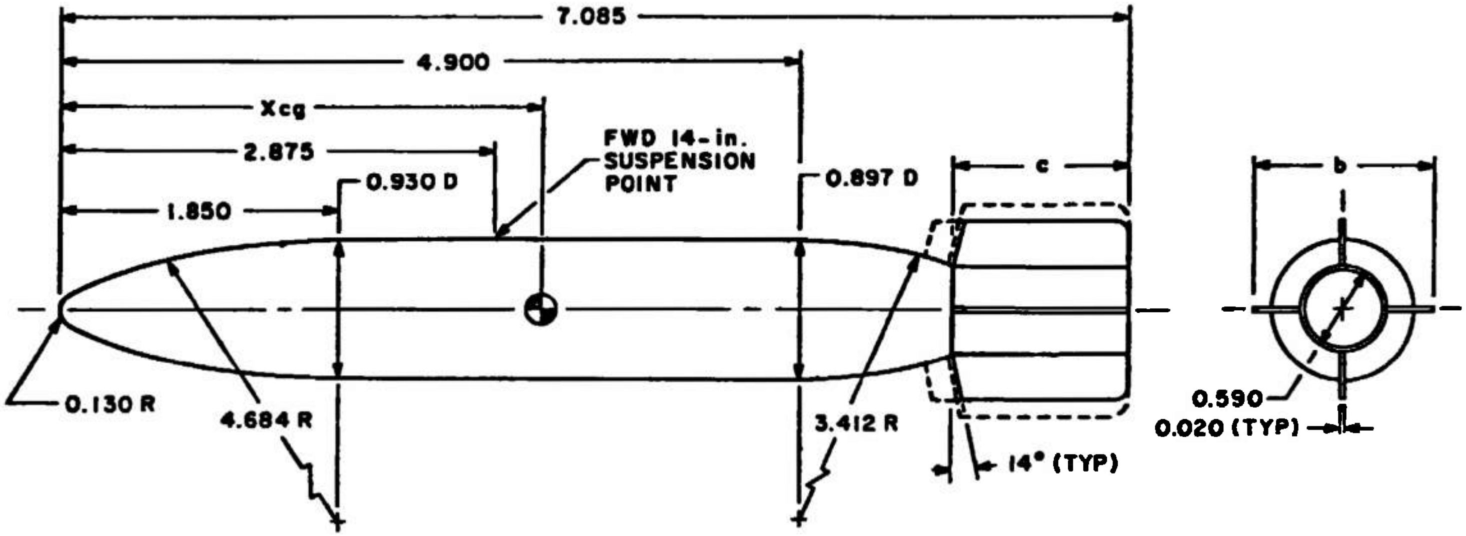


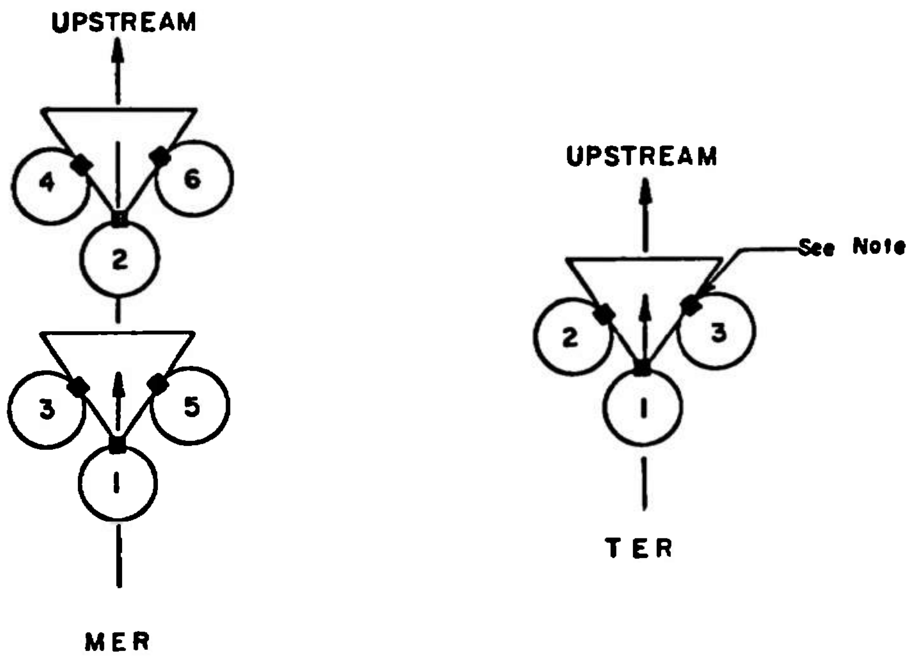
Fig. 9 Details of the CBU-24B/B Models



TAIL	c	AR	b
A	1.166	0.4928	1.200
D1	1.360	0.4612	1.200
D2	1.197	0.7532	1.440

ALL DIMENSIONS IN INCHES

Fig. 10 Details of the Finned BLU-1C/B Models



NOTE: The square indicates the orientation of the suspension lugs

TYPE RACK	STATION	ROLL ORIENTATION, deg
MER	1	0
	2	0
	3	45
	4	45
	5	-45
	6	-45
TER	1	0
	2	45
	3	-45

Fig. 11 Schematic of the MER and TER Store Stations and Orientations

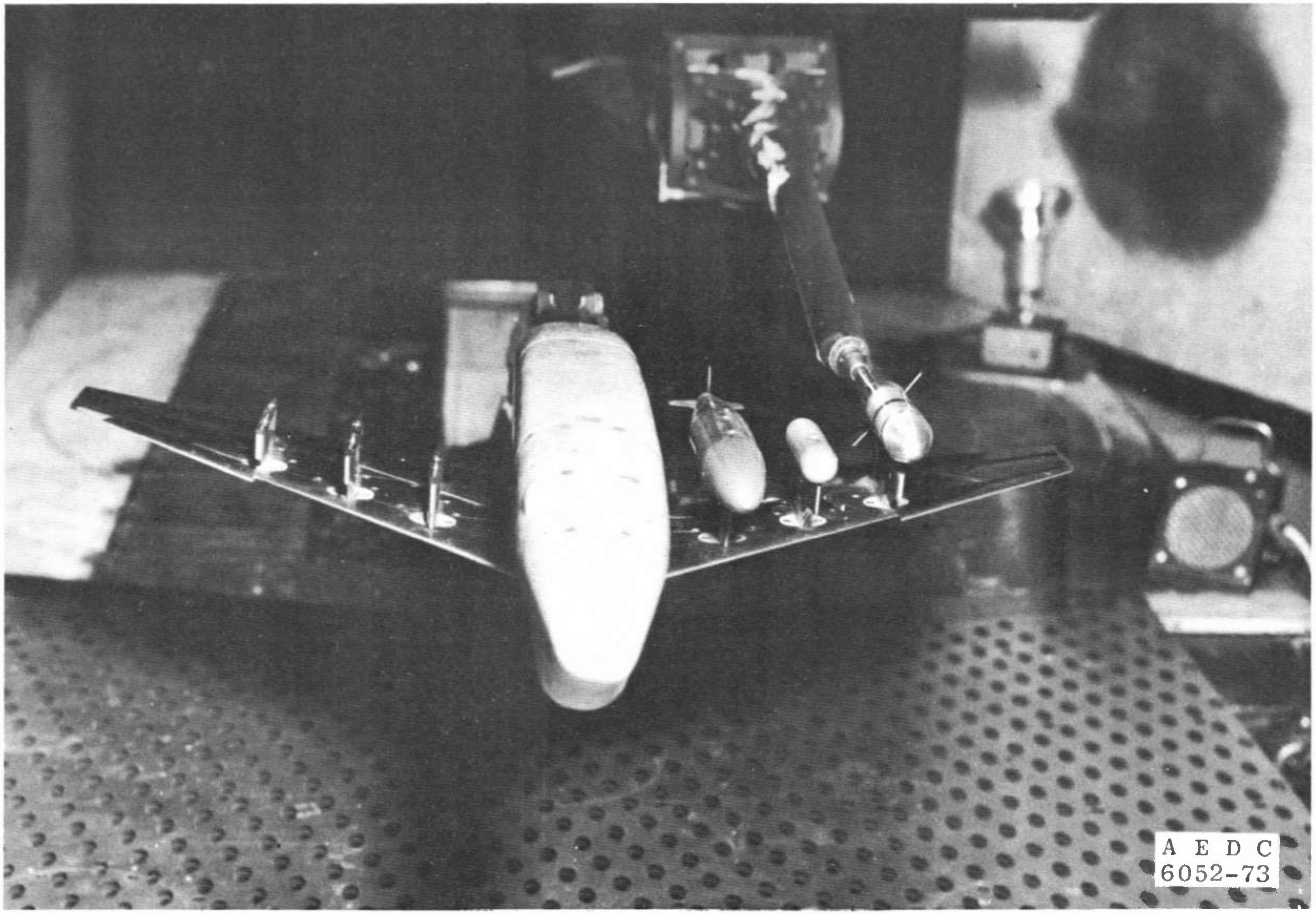
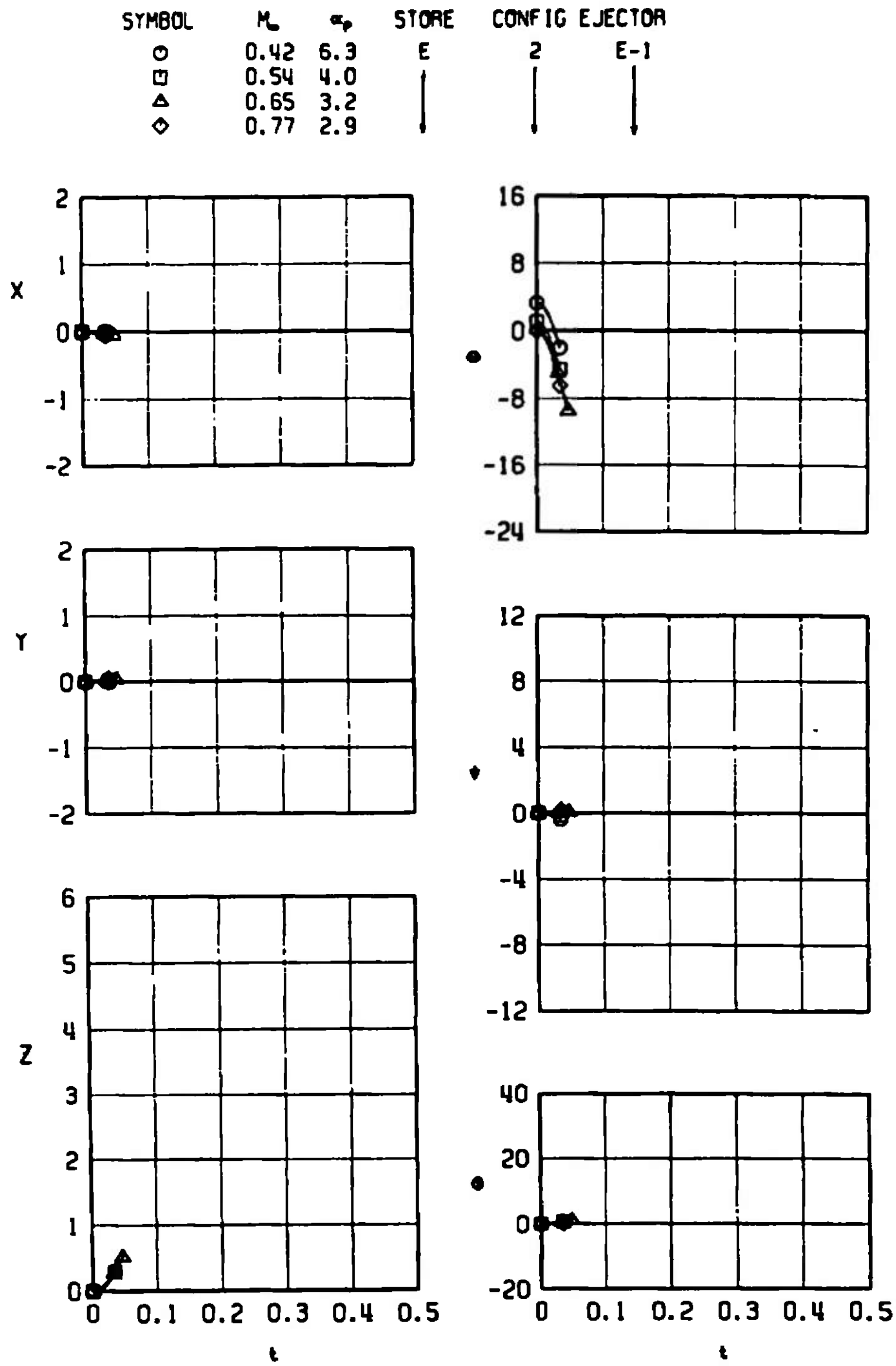
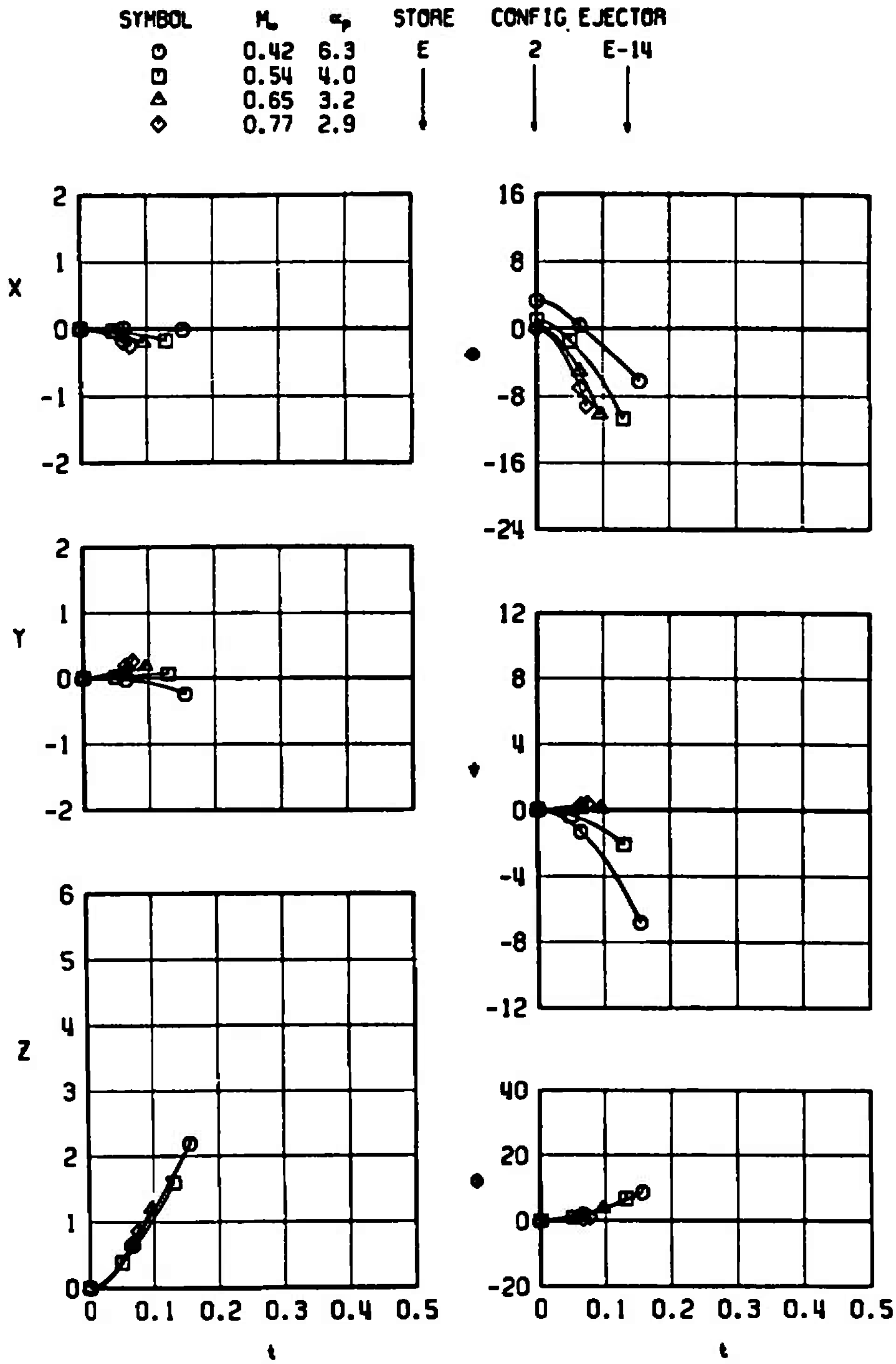


Fig. 12 Tunnel Installation Photograph Showing Parent Aircraft, Store, and CTS



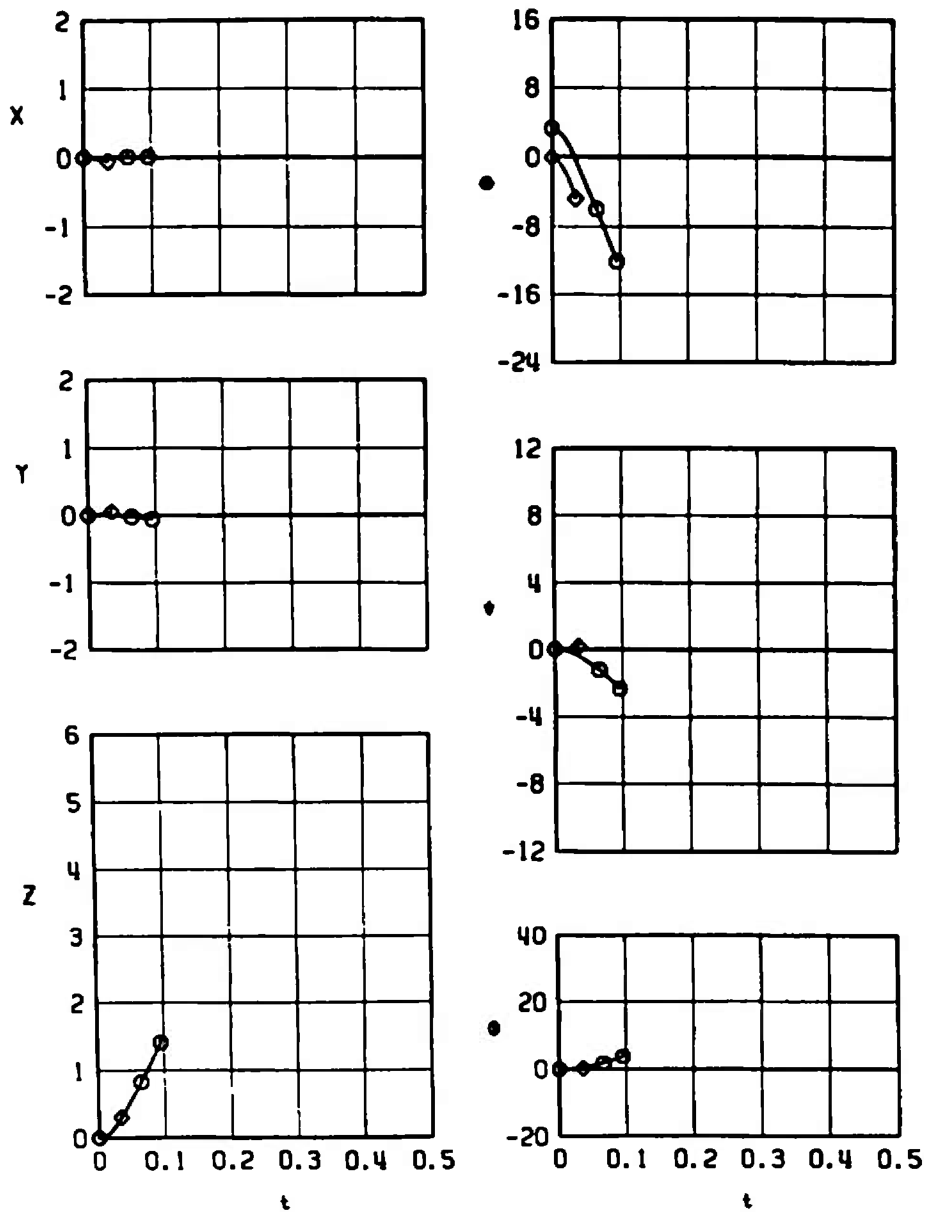
a. Configuration 2, Ejector E-1

Fig. 13 Mach Number Comparison of the CTU-1/A "E" Series Launch Trajectories for Different Ejector Forces

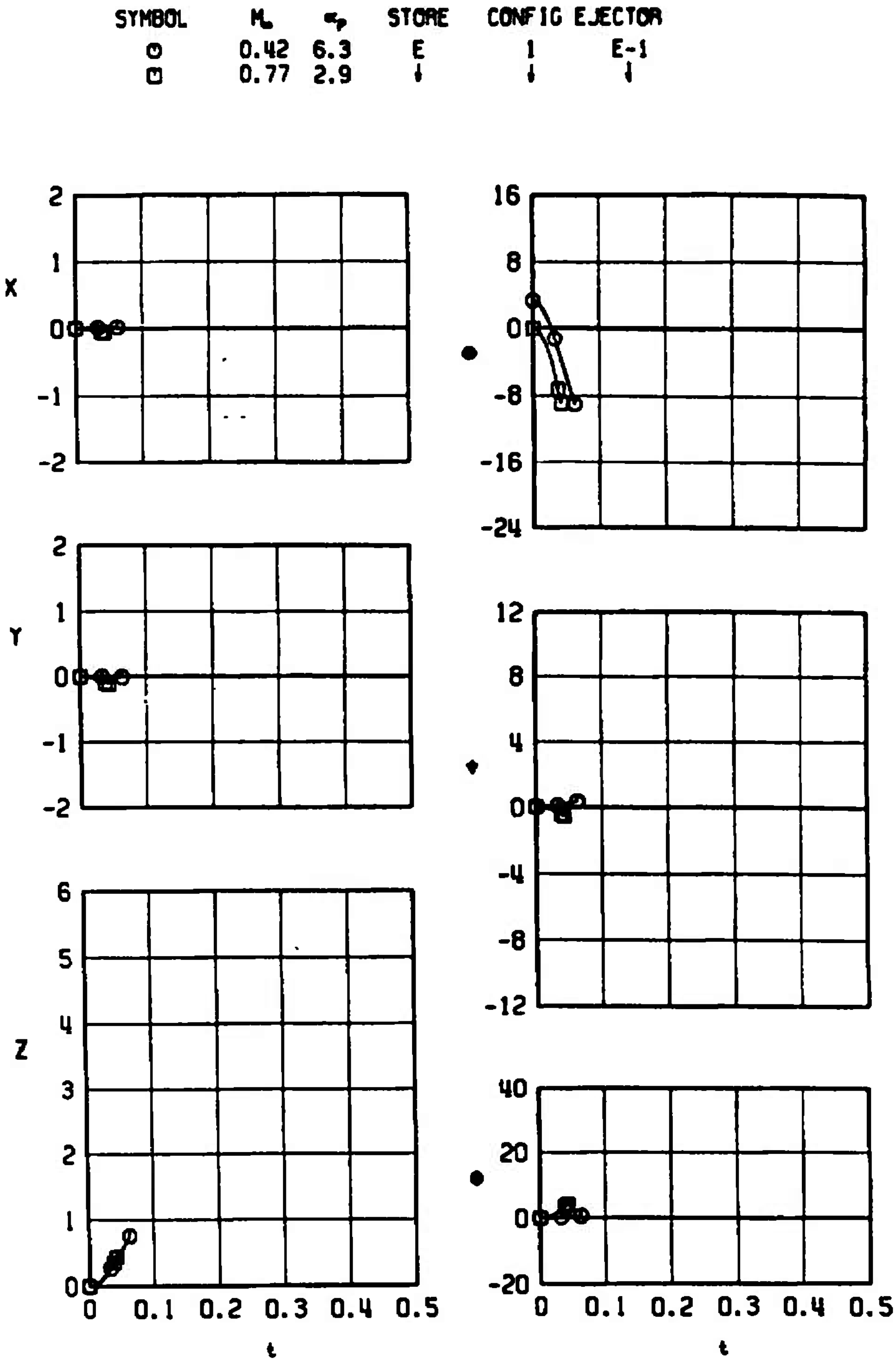


b. Configuration 2, Ejector E-14
Fig. 13 Continued

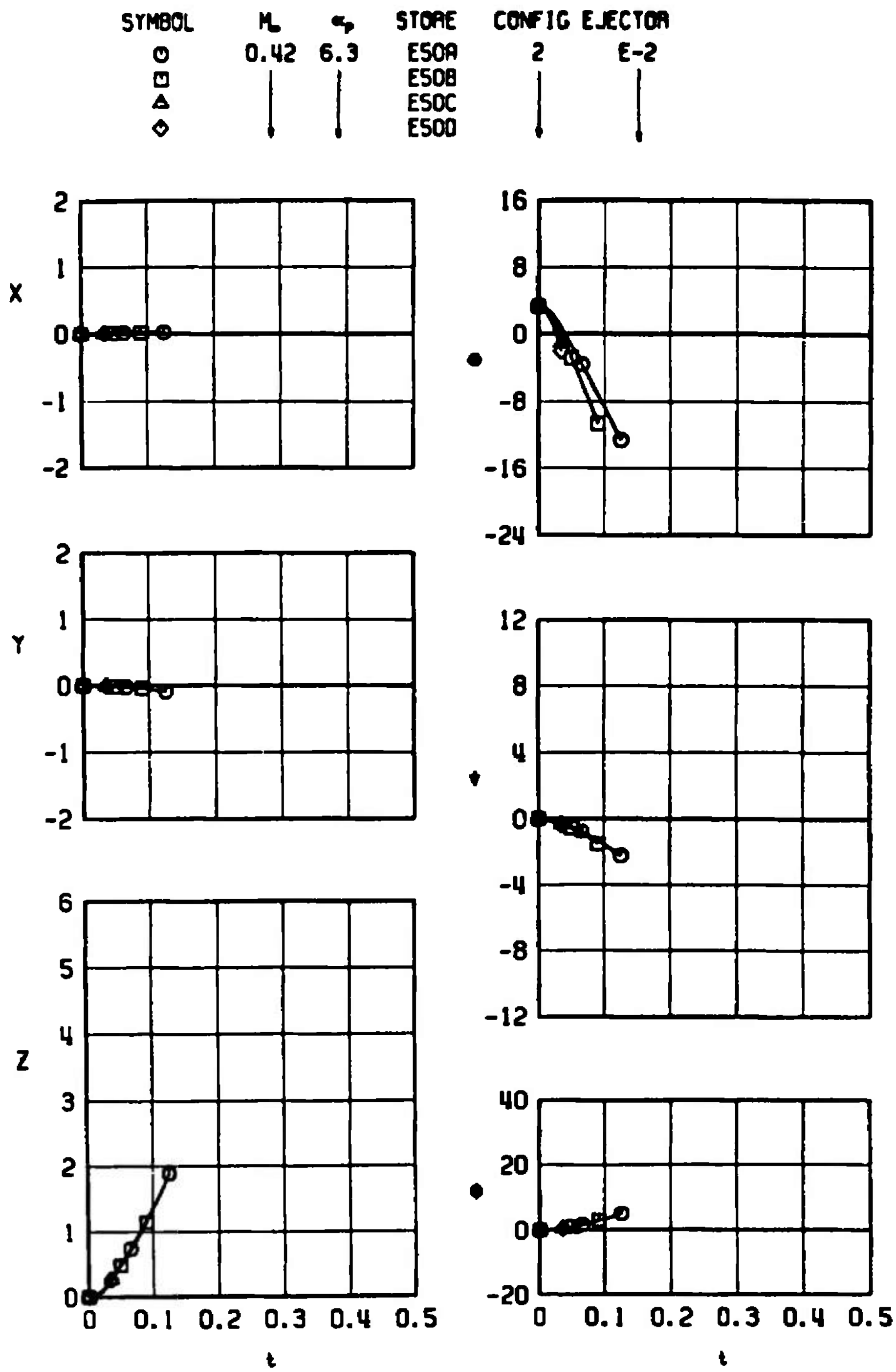
SYMBOL	M_∞	α_p	STORE	CONFIG	EJECTOR
○	0.42	6.3	E	2	E-18
◇	0.77	2.9	↓	↓	↓



c. Configuration 2, Ejector E-18
Fig. 13 Continued

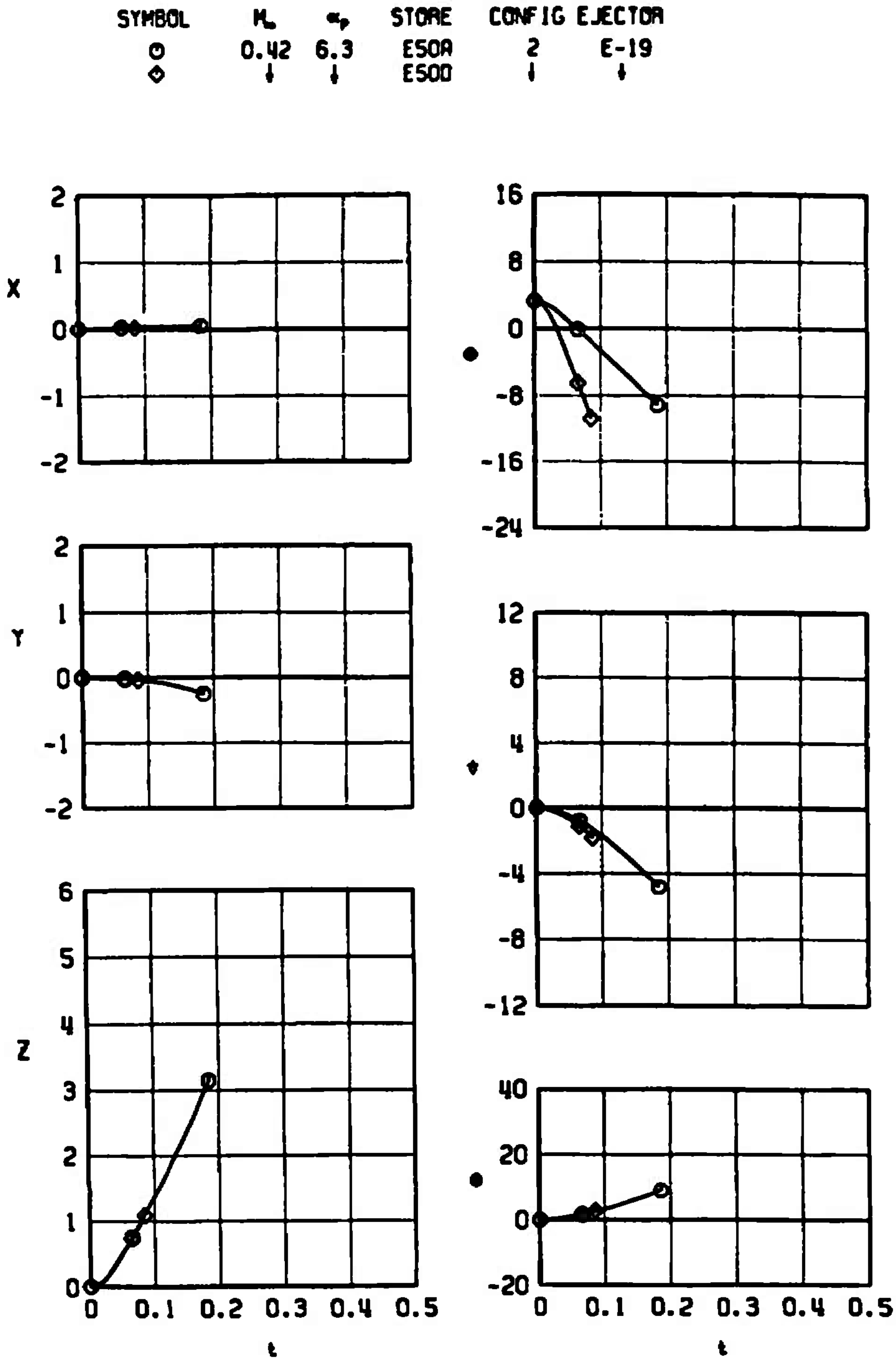


d. Configuration 1, Ejector E-1
Fig. 13 Concluded

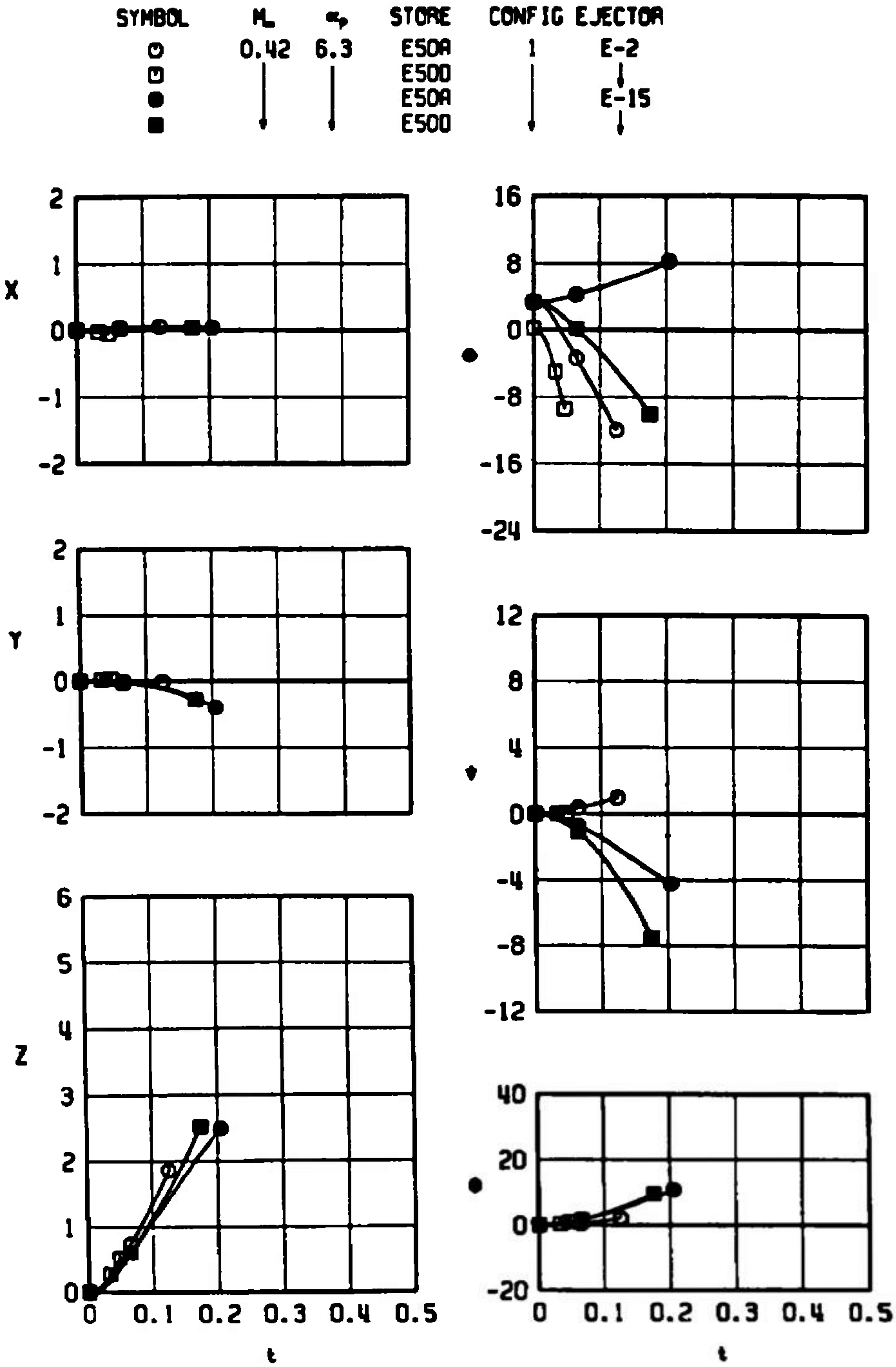


a. Configuration 2, M_∞ = 0.42, Ejector E-2

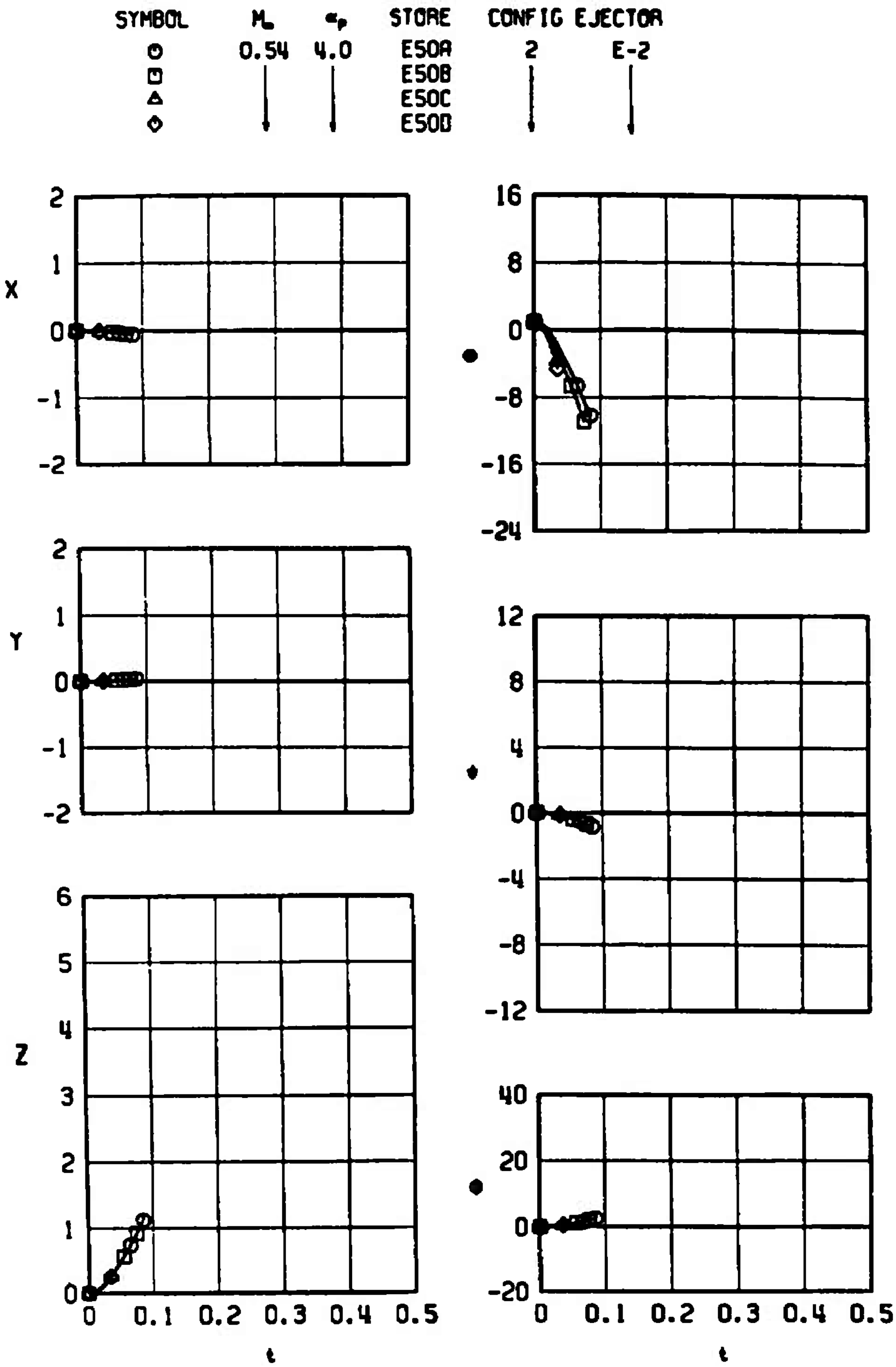
Fig. 14 Effects of Store cg Location on the CTU-1/A "E50" Series Launch Trajectories for Different Mach Numbers and Ejector Forces



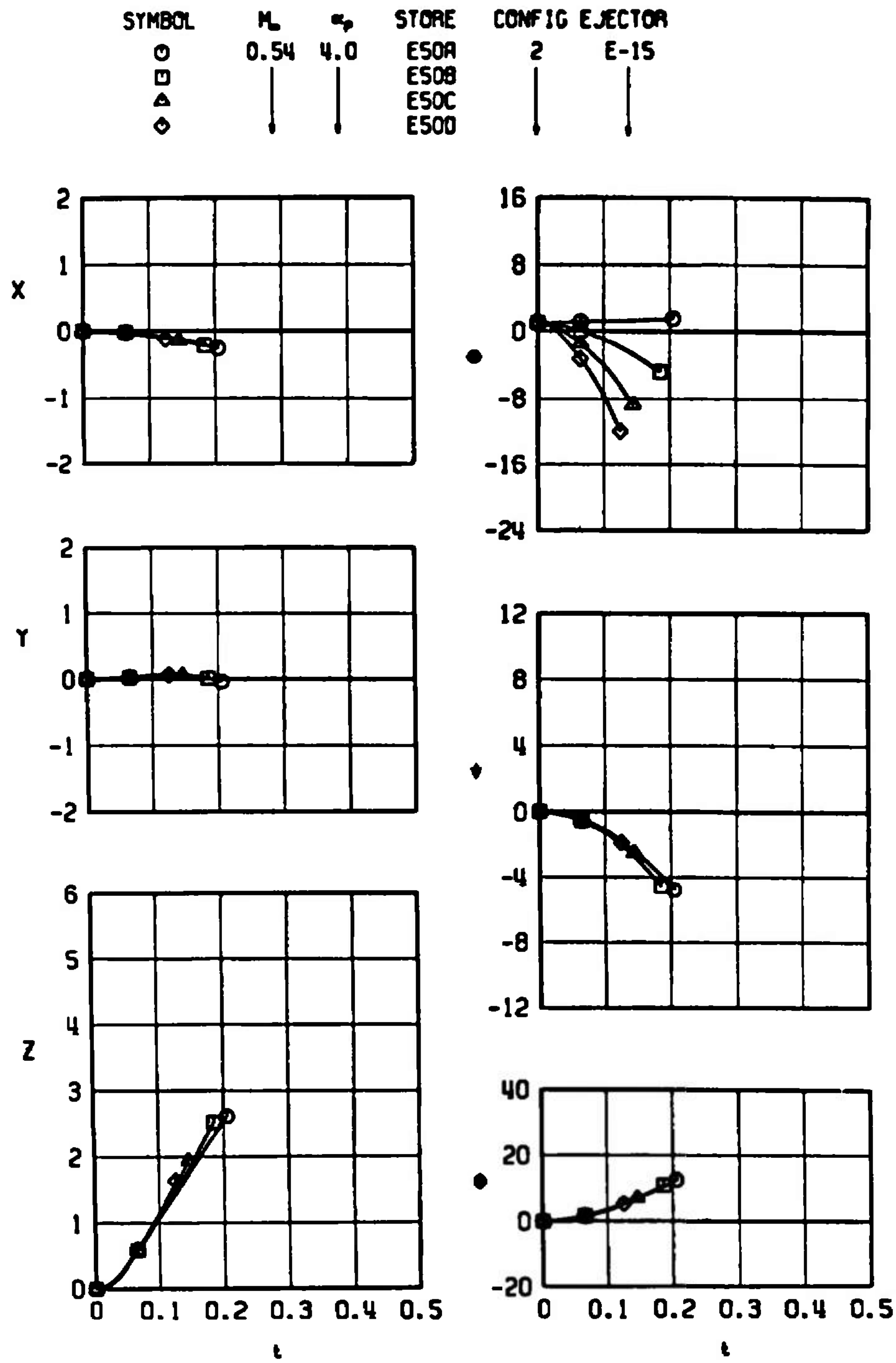
b. Configuration 2, M_∞ = 0.42, Ejector E-19
Fig. 14 Continued



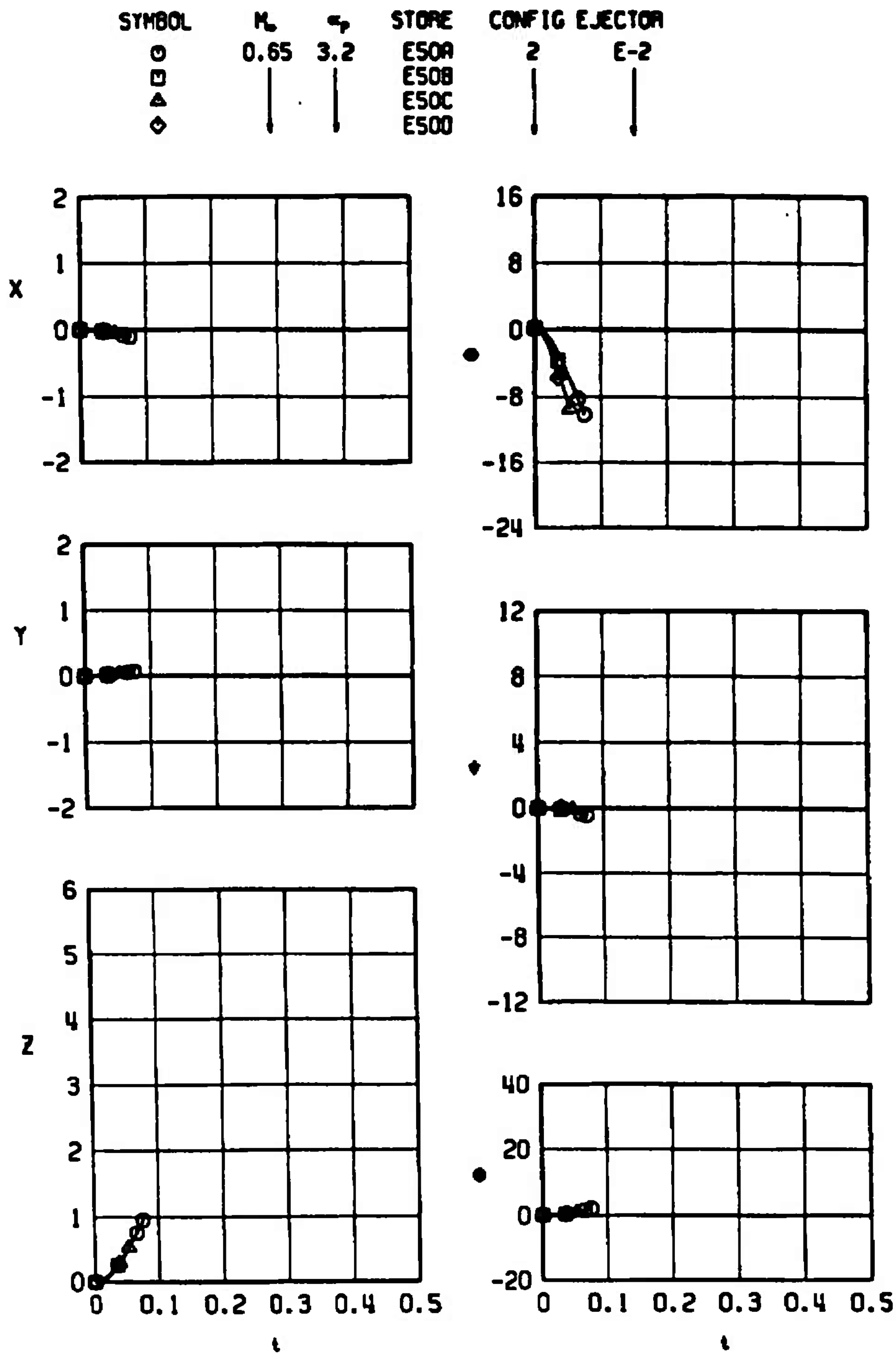
c. Configuration 1, M_∞ = 0.42, Ejectors E-2 and E-15
Fig. 14 Continued



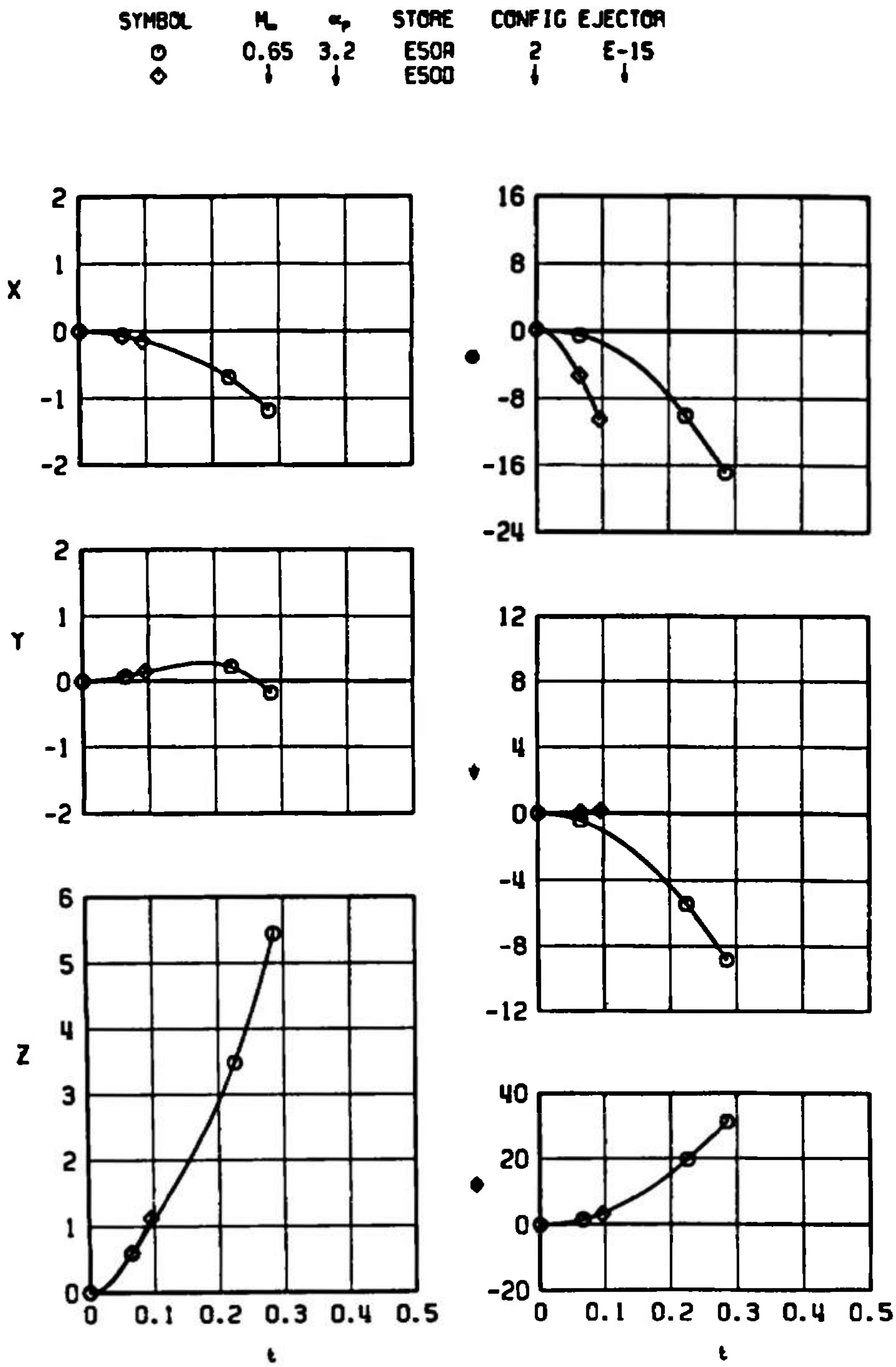
d. Configuration 2, M_∞ = 0.54, Ejector E-2
Fig. 14 Continued



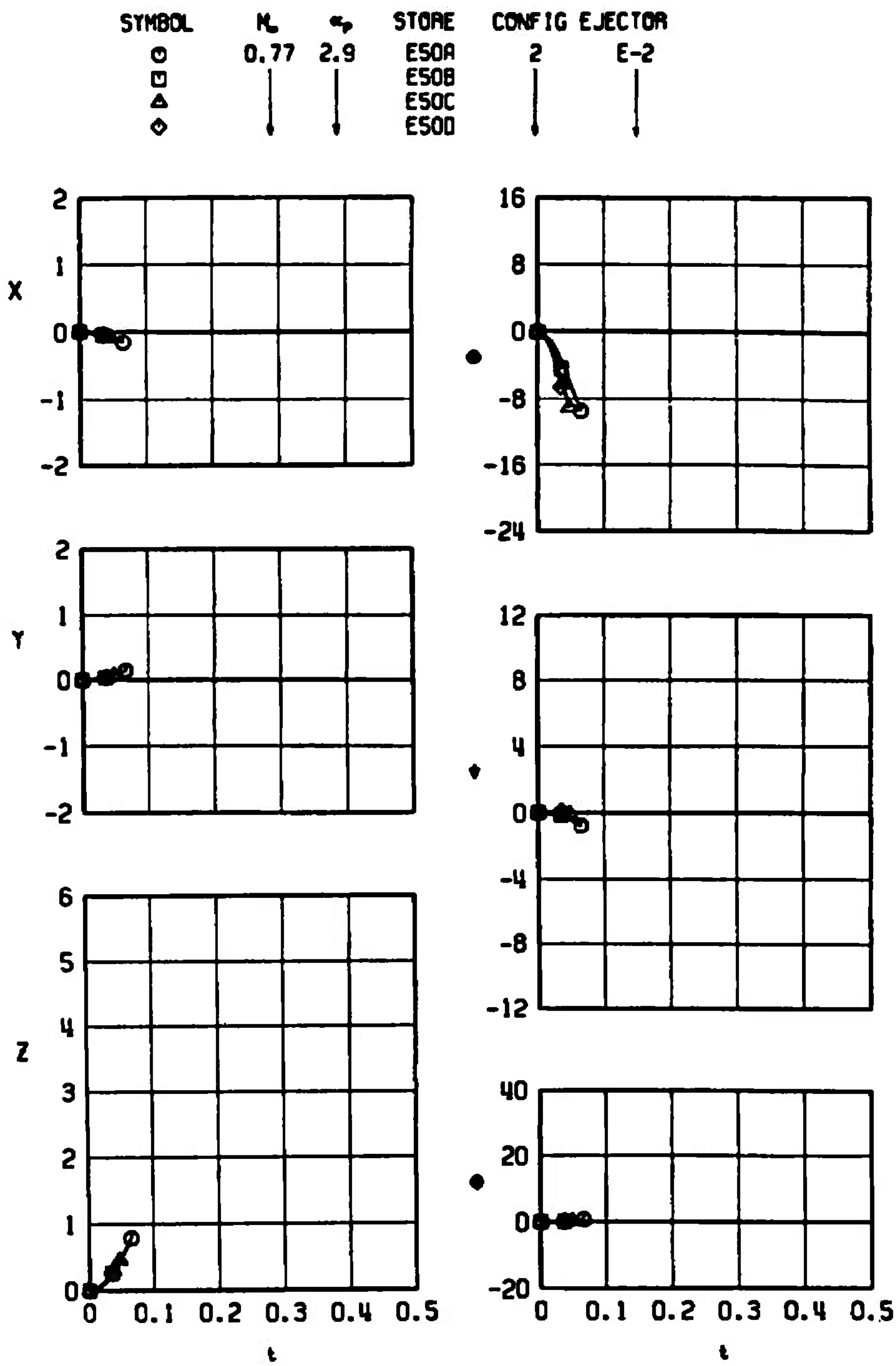
e. Configuration 2, M_∞ = 0.54, Ejector E-15
Fig. 14 Continued



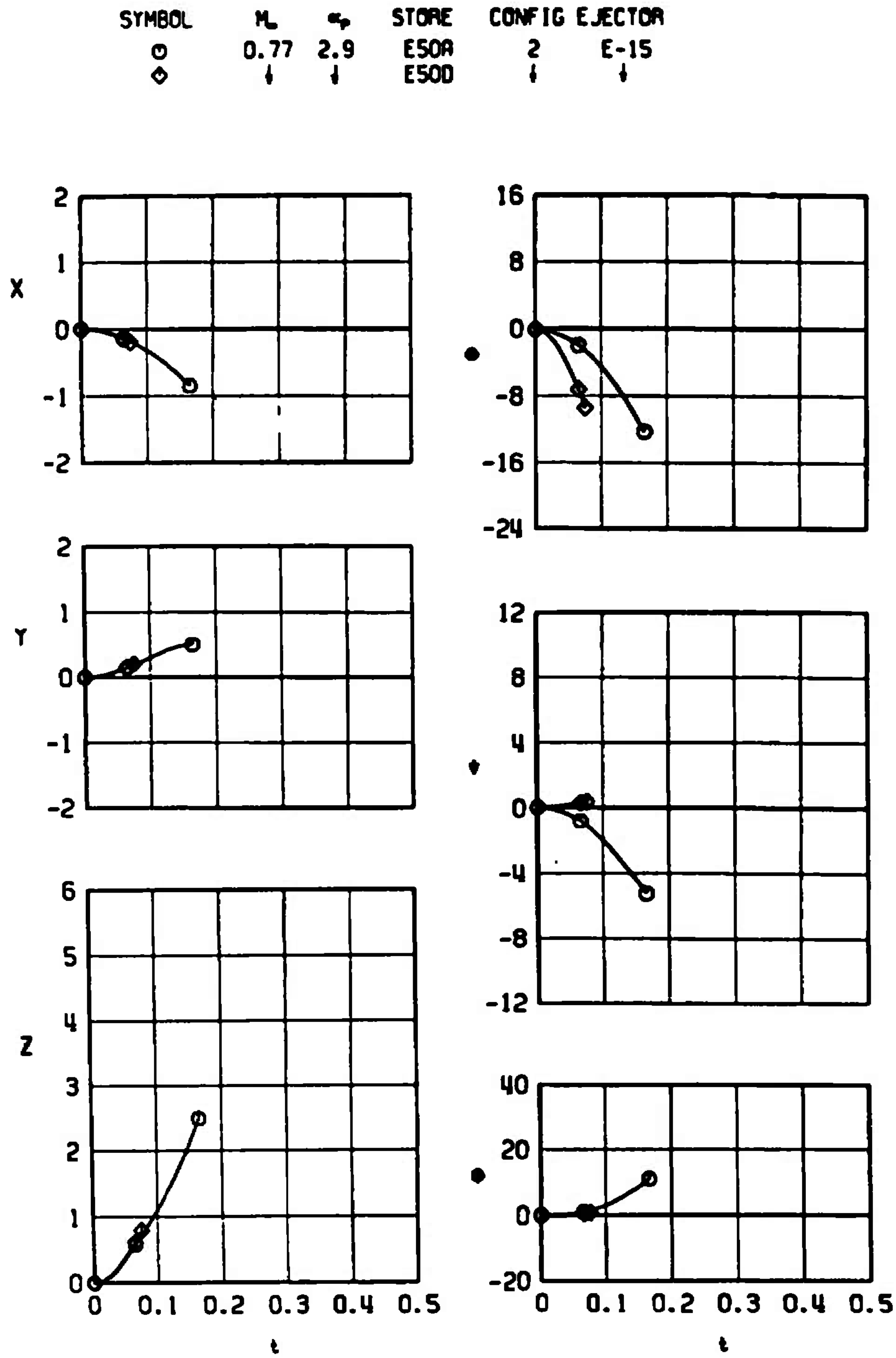
f. Configuration 2, M_∞ = 0.65, Ejector E-2
Fig. 14 Continued



g. Configuration 2, M_∞ = 0.65, Ejector E-15
Fig. 14 Continued

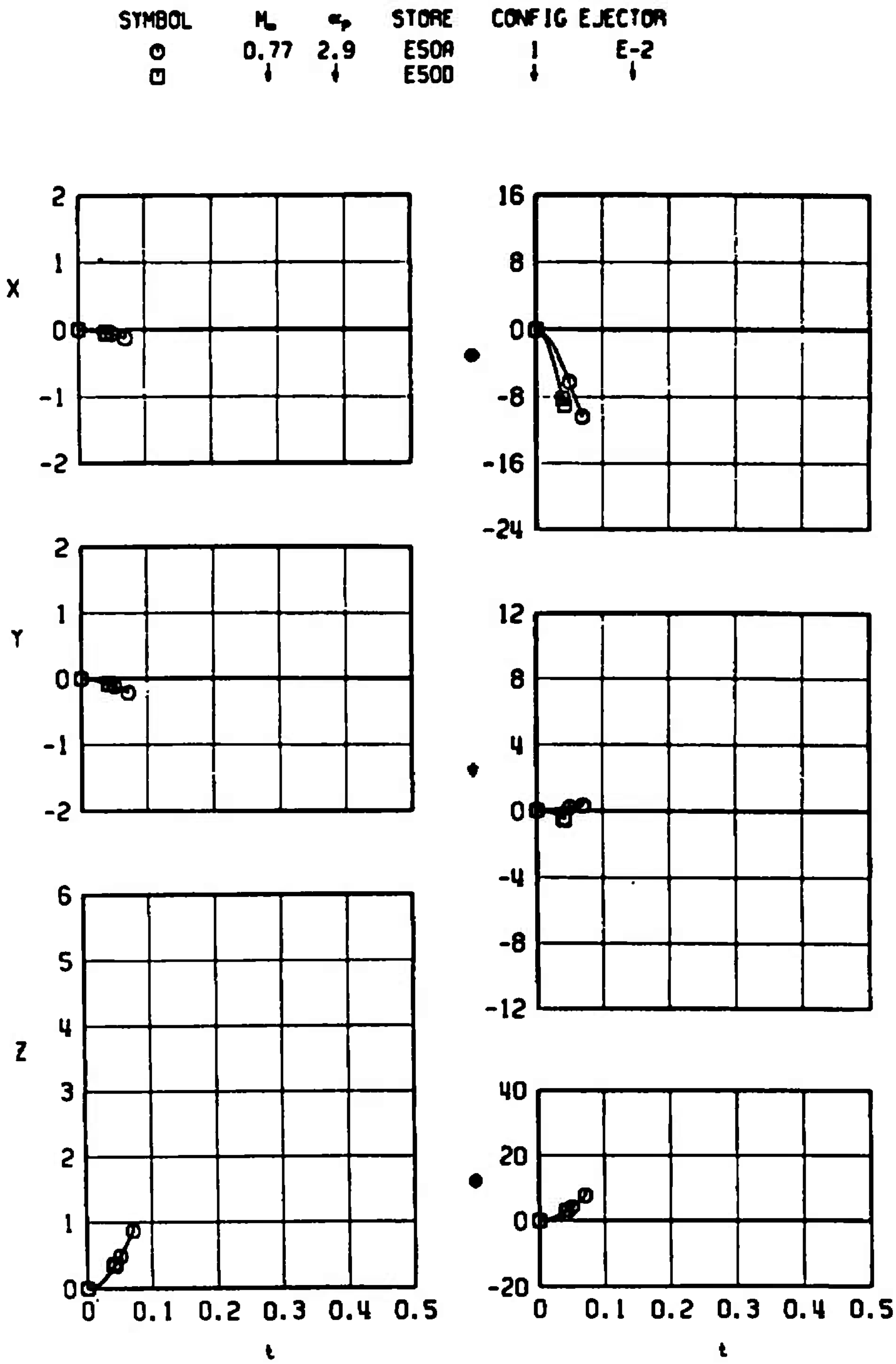


h. Configuration 2, M_∞ = 0.77, Ejector E-2
Fig. 14 Continued

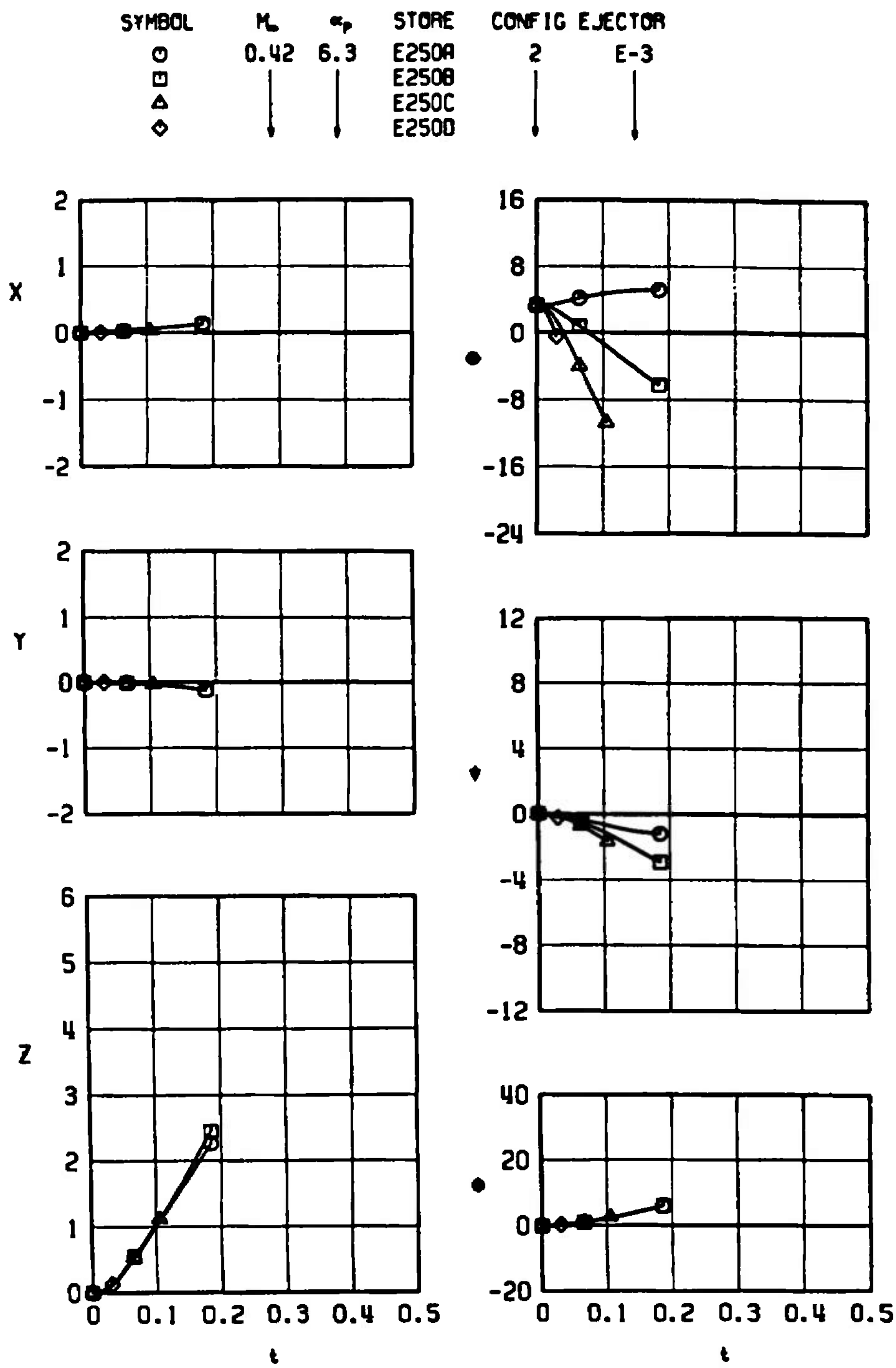


i. Configuration 2, M_∞ = 0.77, Ejector E-15

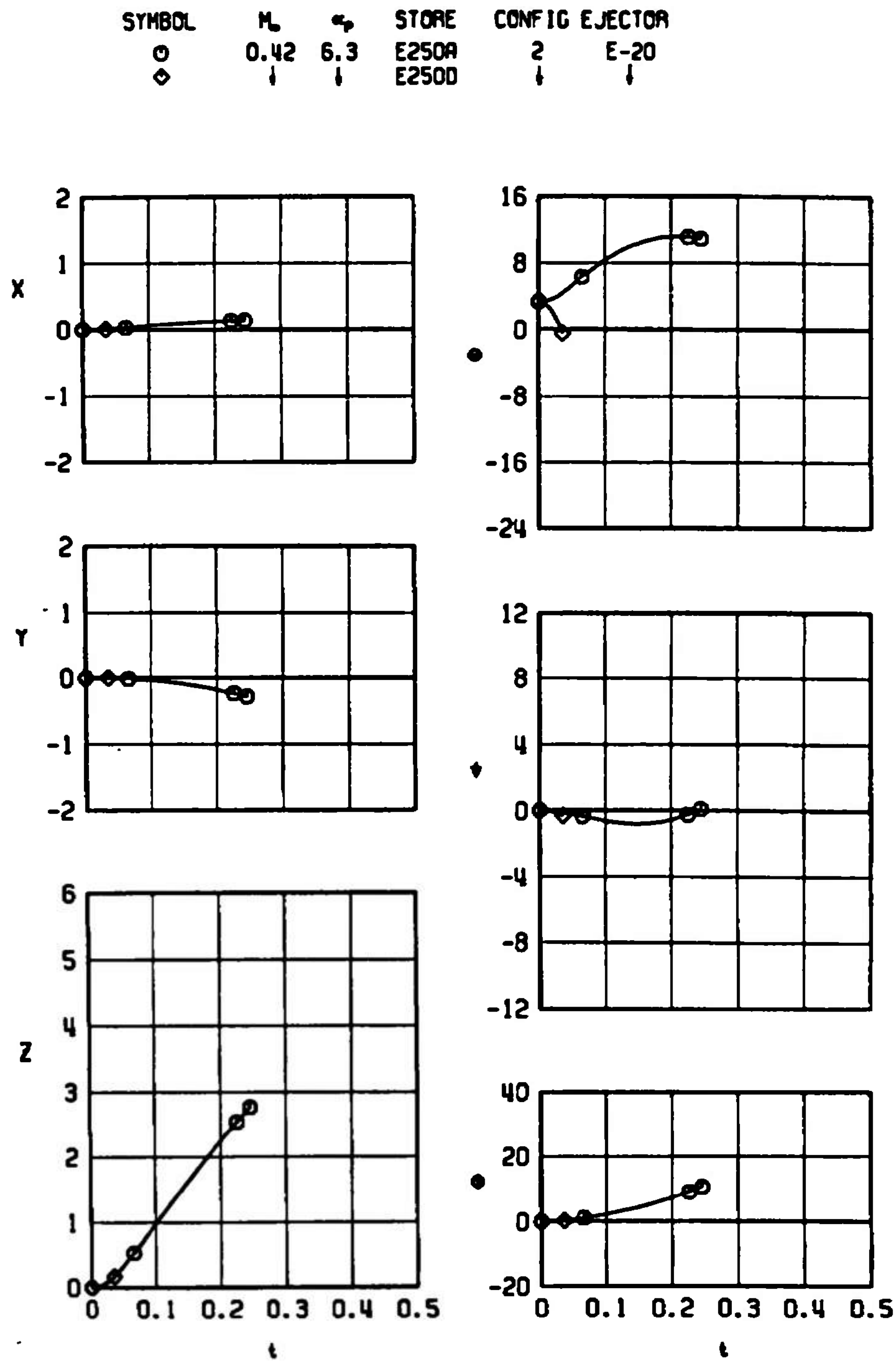
Fig. 14 Continued



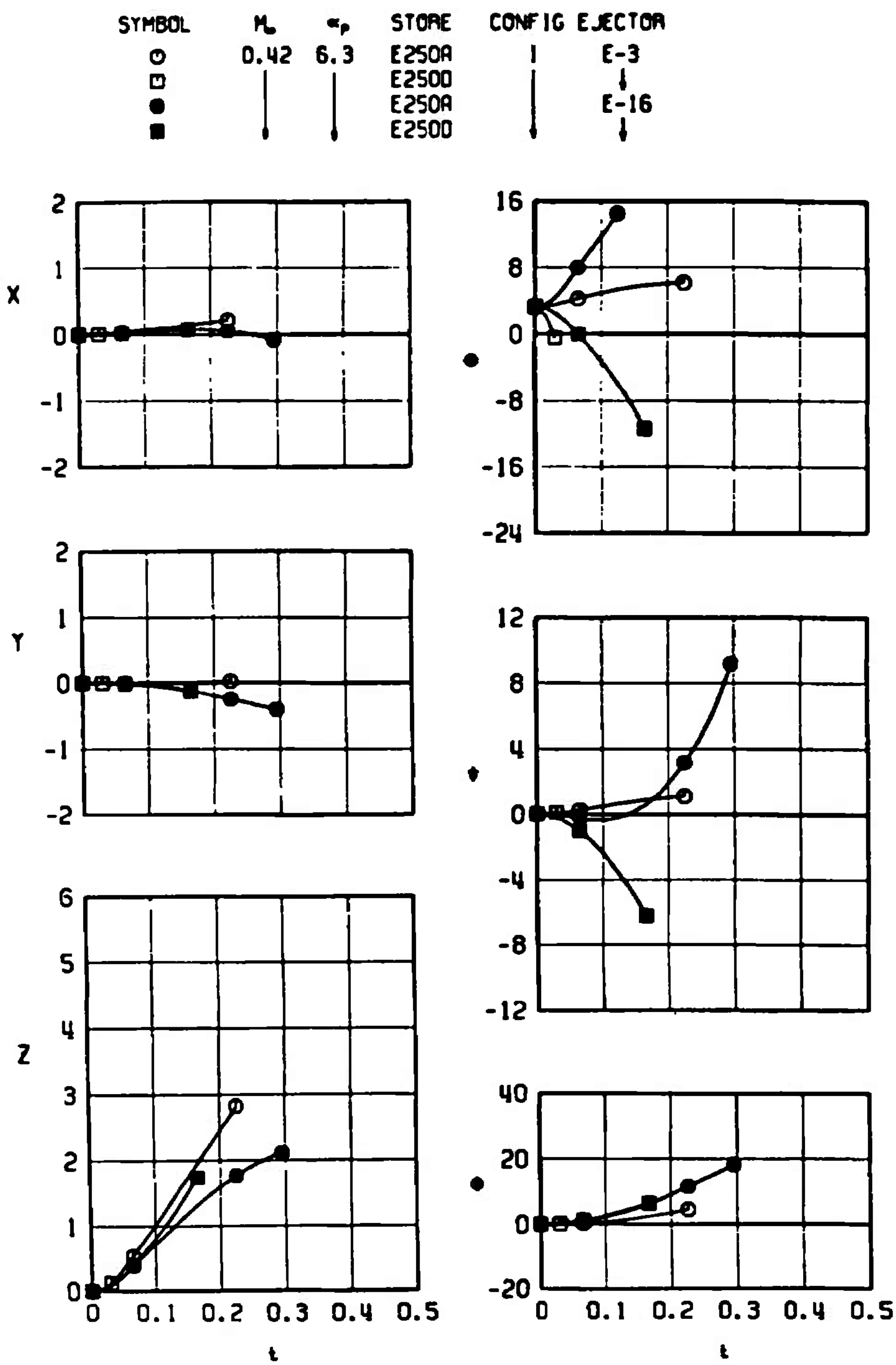
j. Configuration 1, M_∞ = 0.77, Ejector E-2
Fig. 14 Concluded



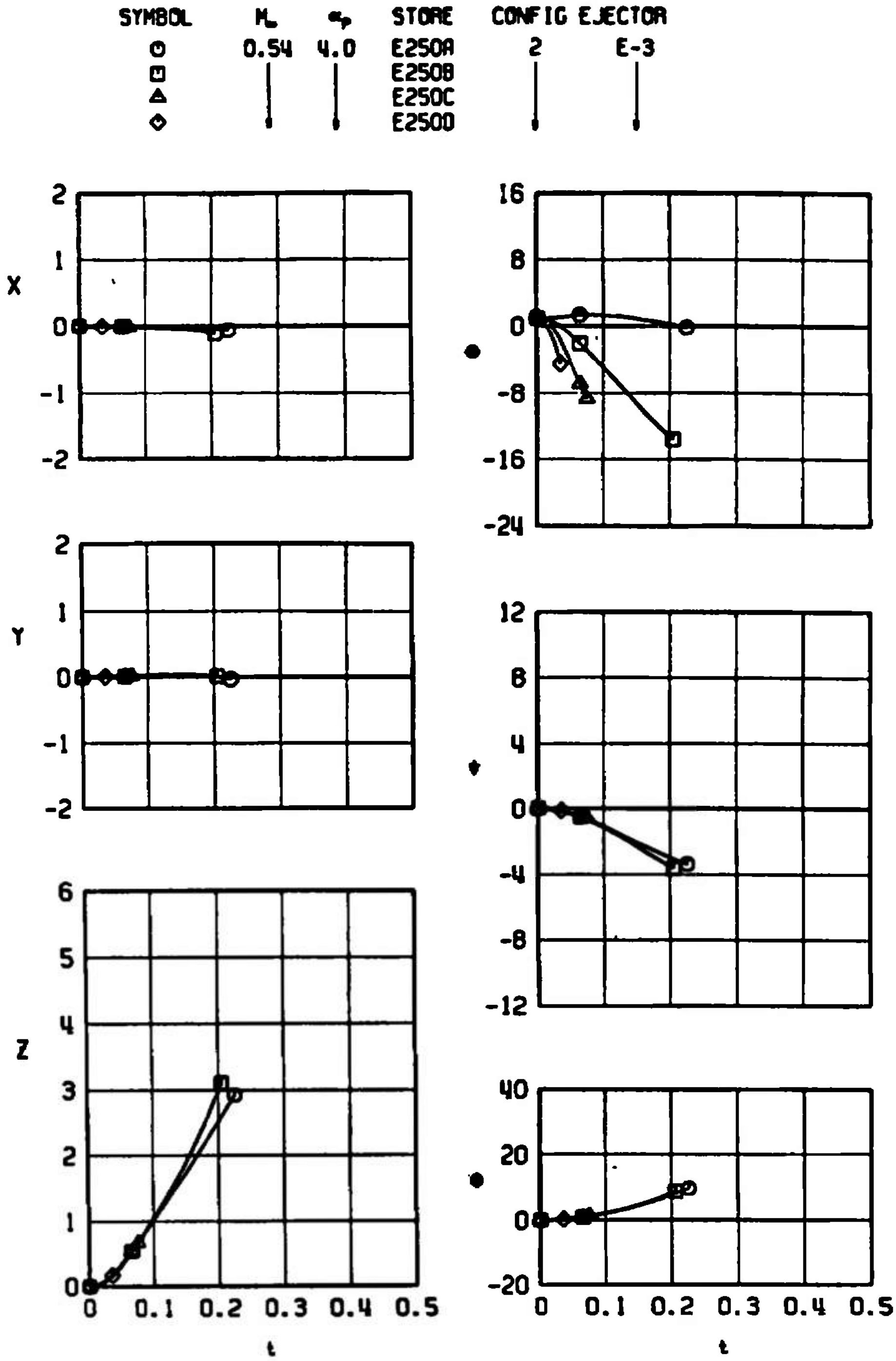
a. Configuration 2, M_∞ = 0.42, Ejector E-3
Fig. 15 Effects of Store cg Location on the CTU-1/A "E250" Series Launch Trajectories for Different Mach Numbers and Ejector Forces



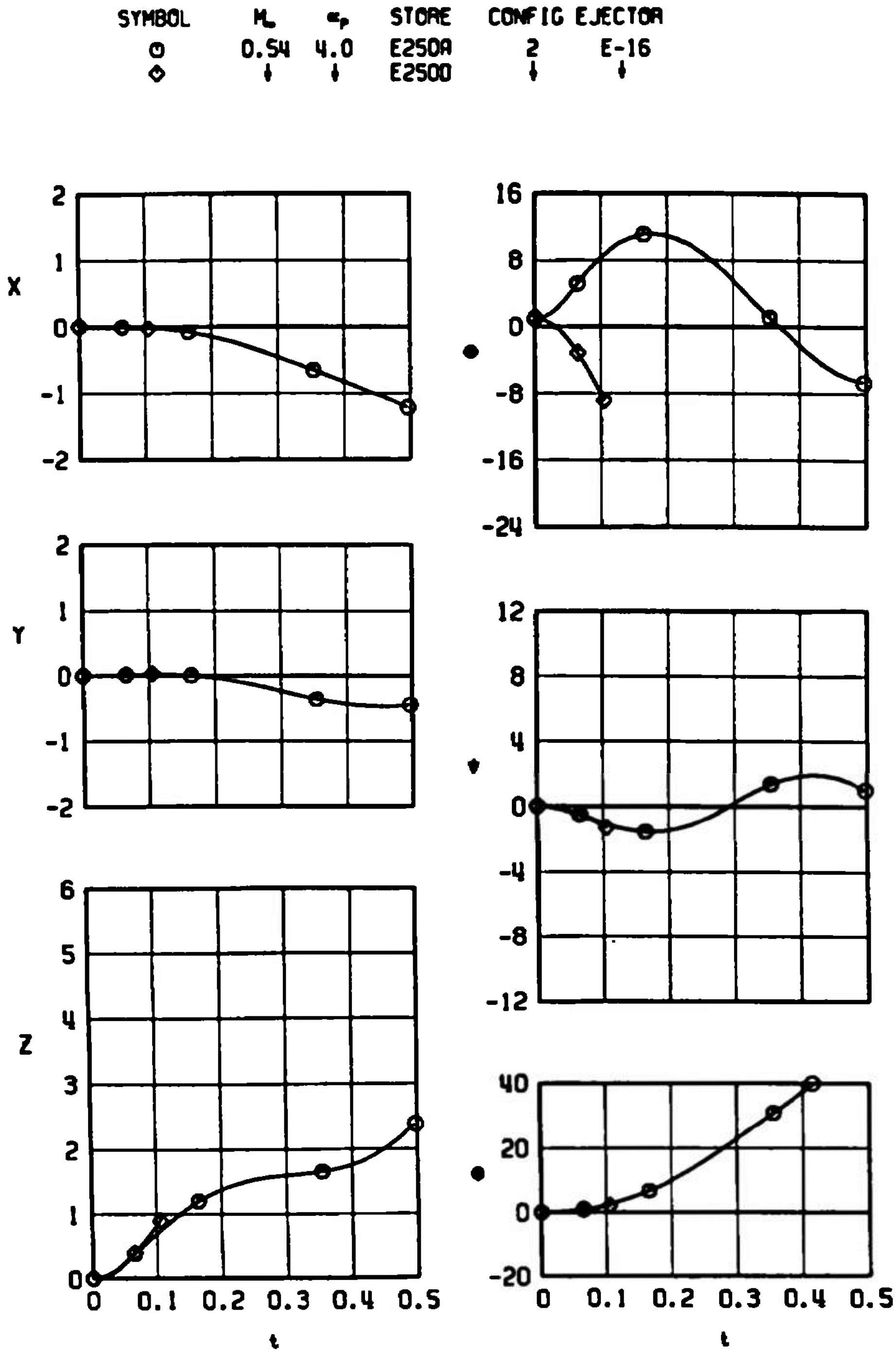
b. Configuration 2, M_∞ = 0.42, Ejector E-20
Fig. 15 Continued



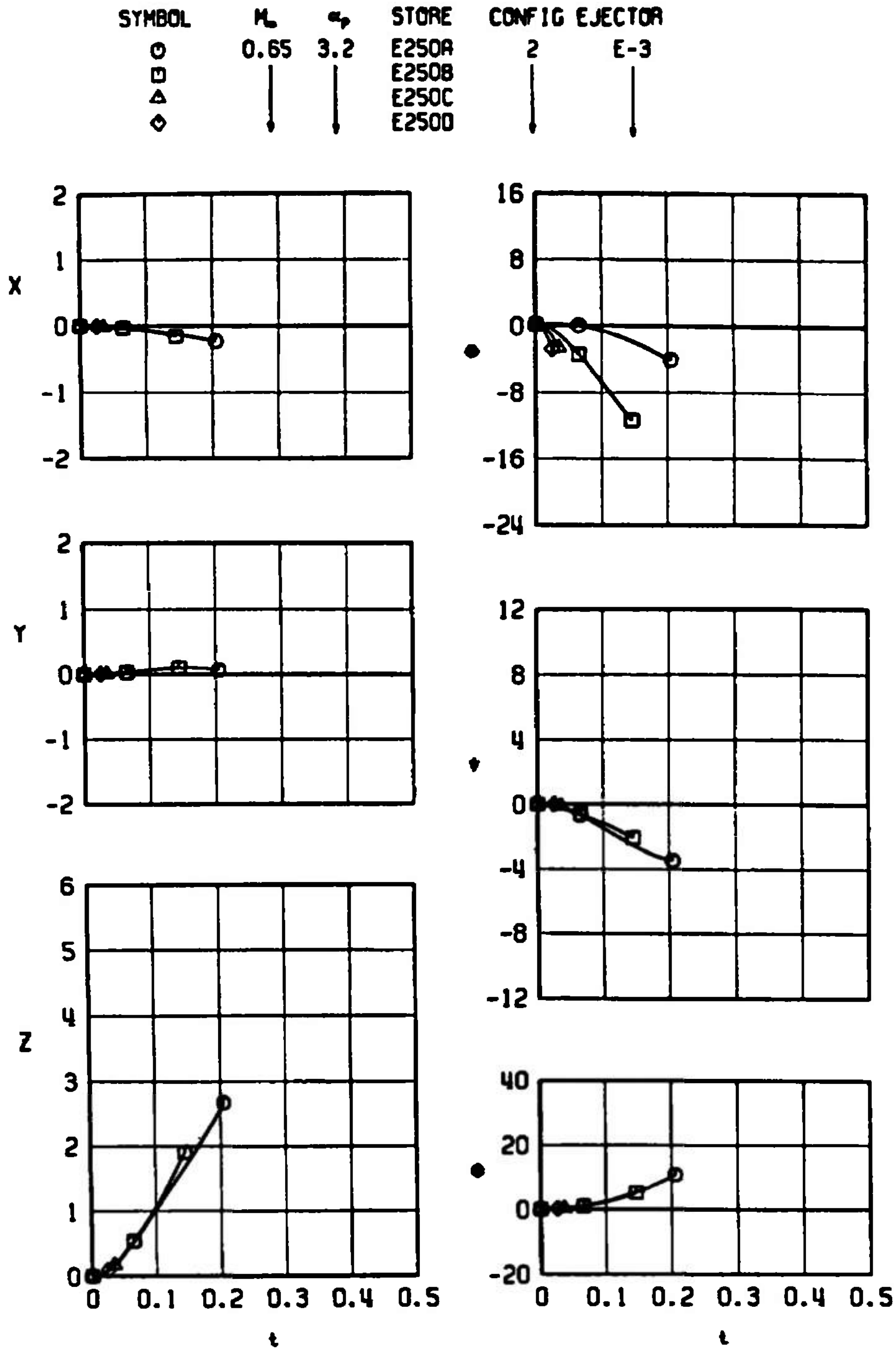
c. Configuration 1, M_∞ = 0.42, Ejectors E-3 and E-16
Fig. 15 Continued



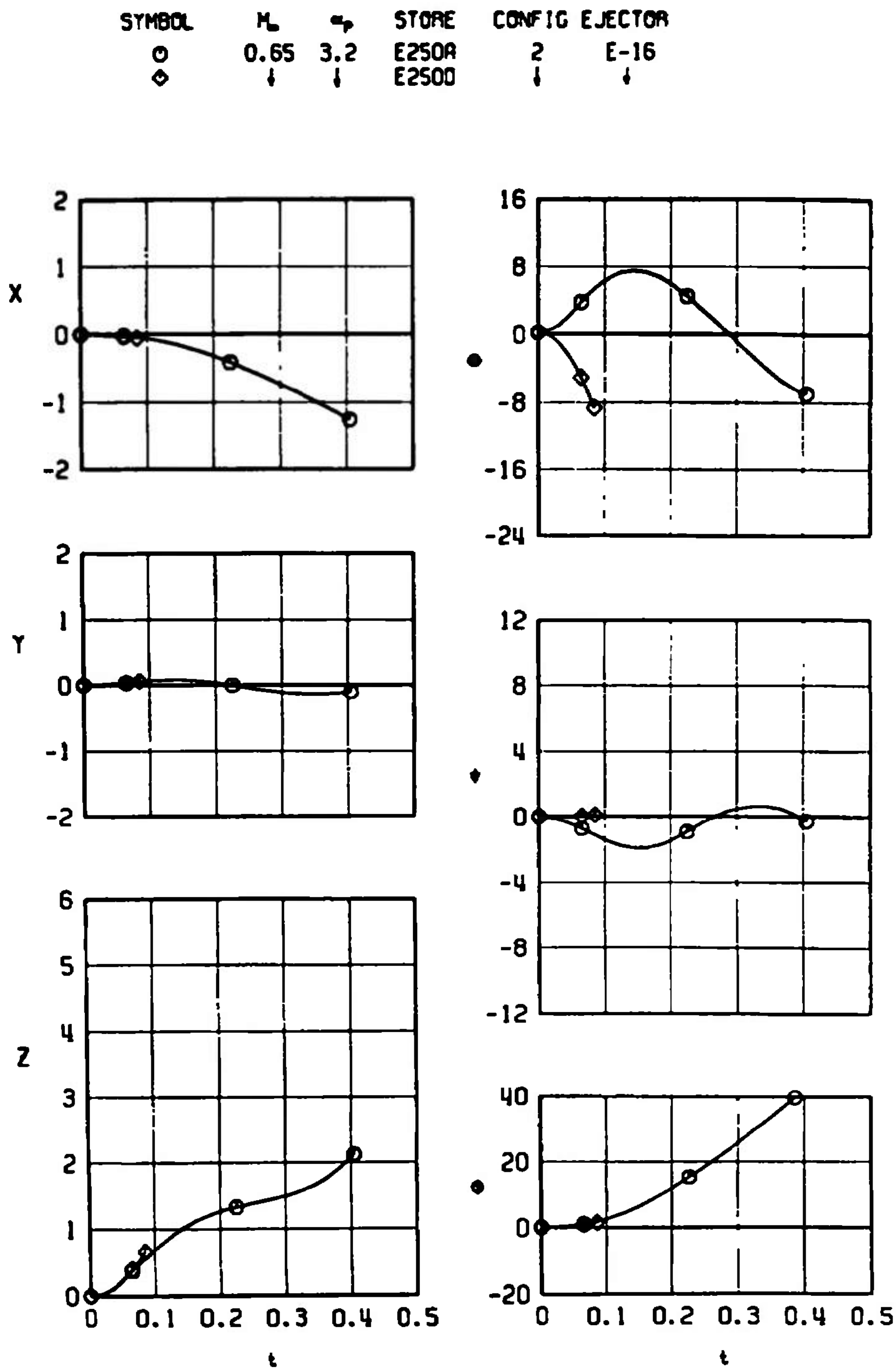
d. Configuration 2, M_∞ = 0.54, Ejector E-3
Fig. 15 Continued



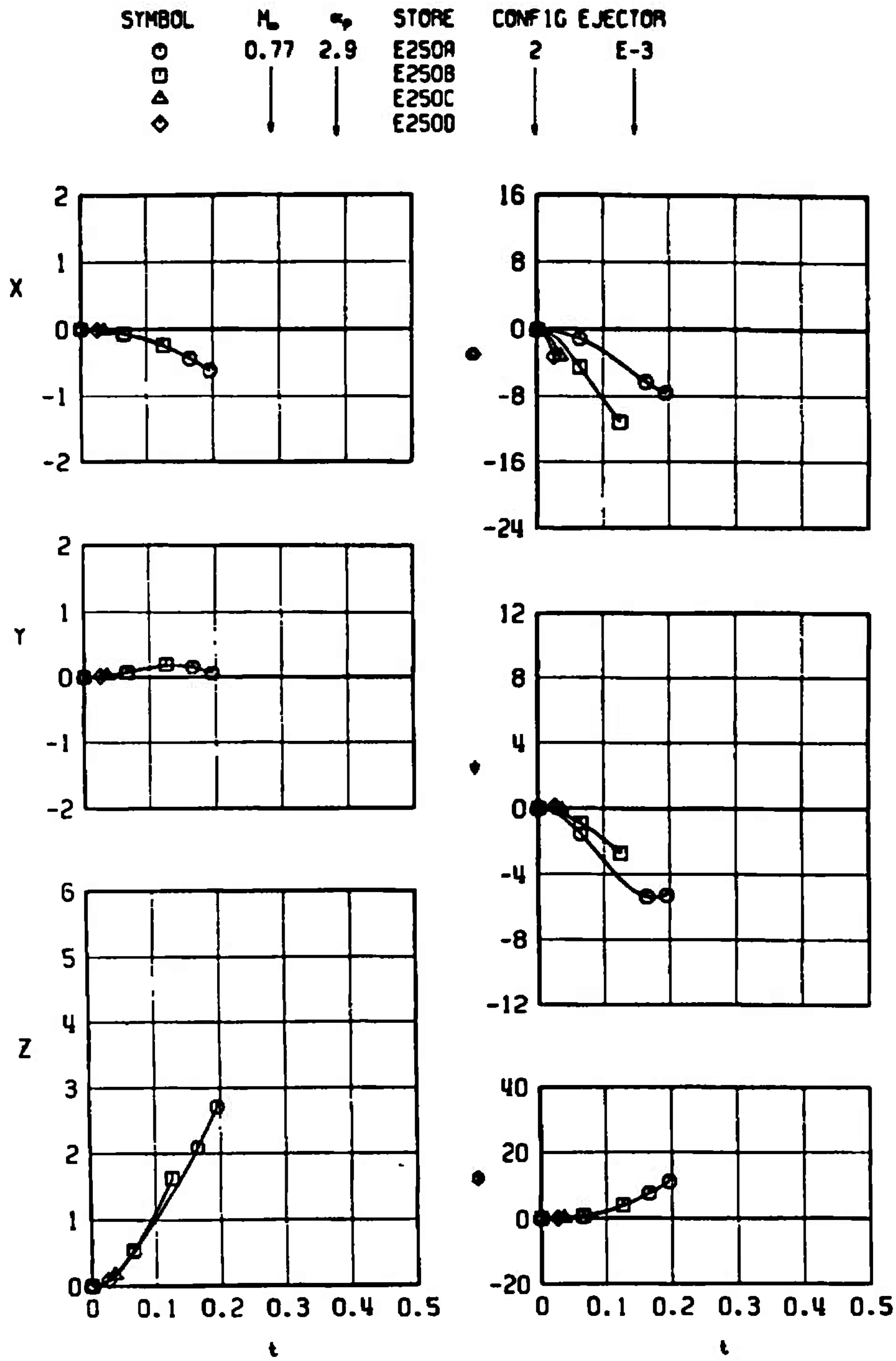
e. Configuration 2, $M_\infty = 0.54$, Ejector E-16
Fig. 15 Continued



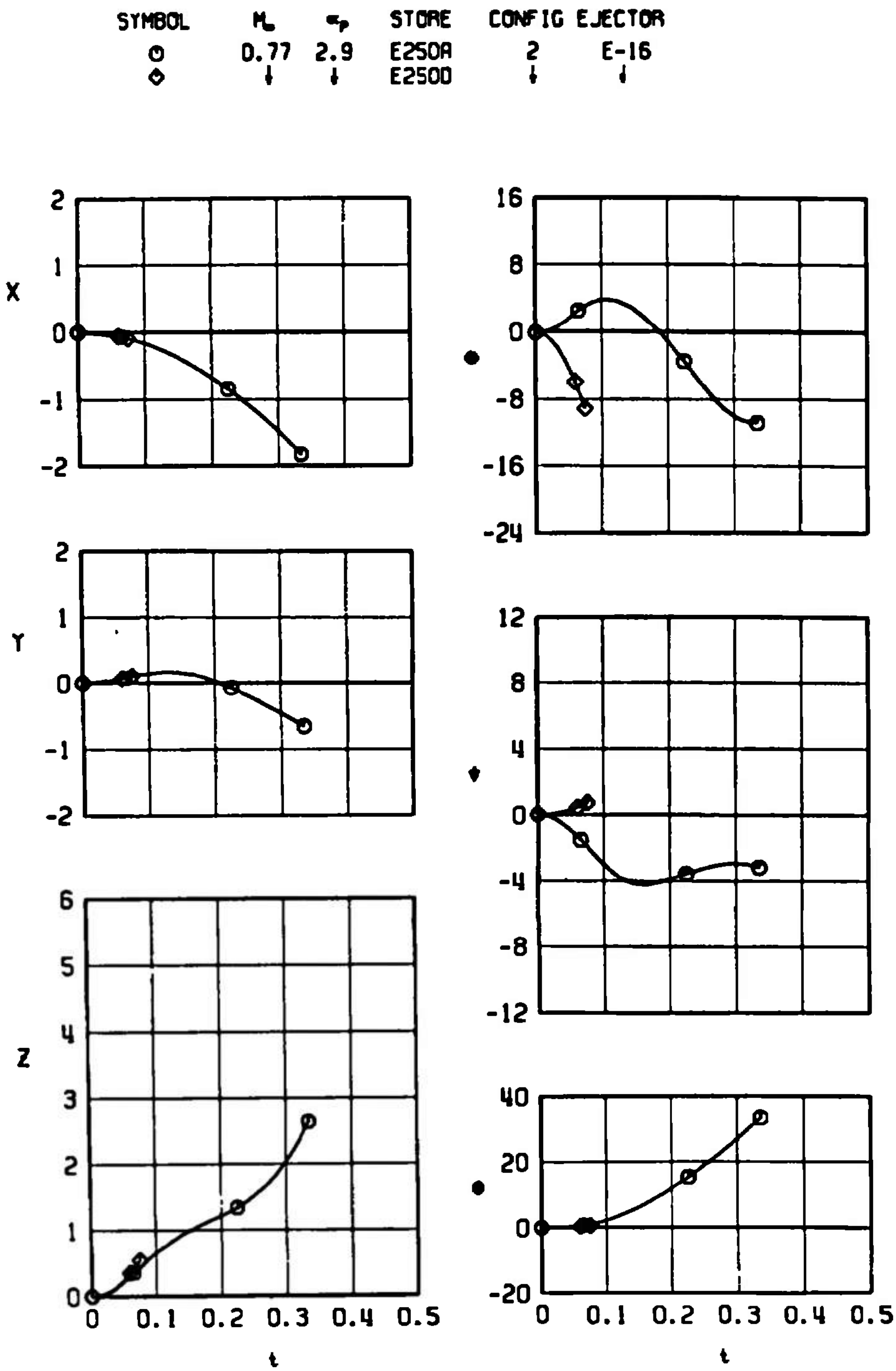
f. Configuration 2, M_∞ = 0.65, Ejector E-3
Fig. 15 Continued



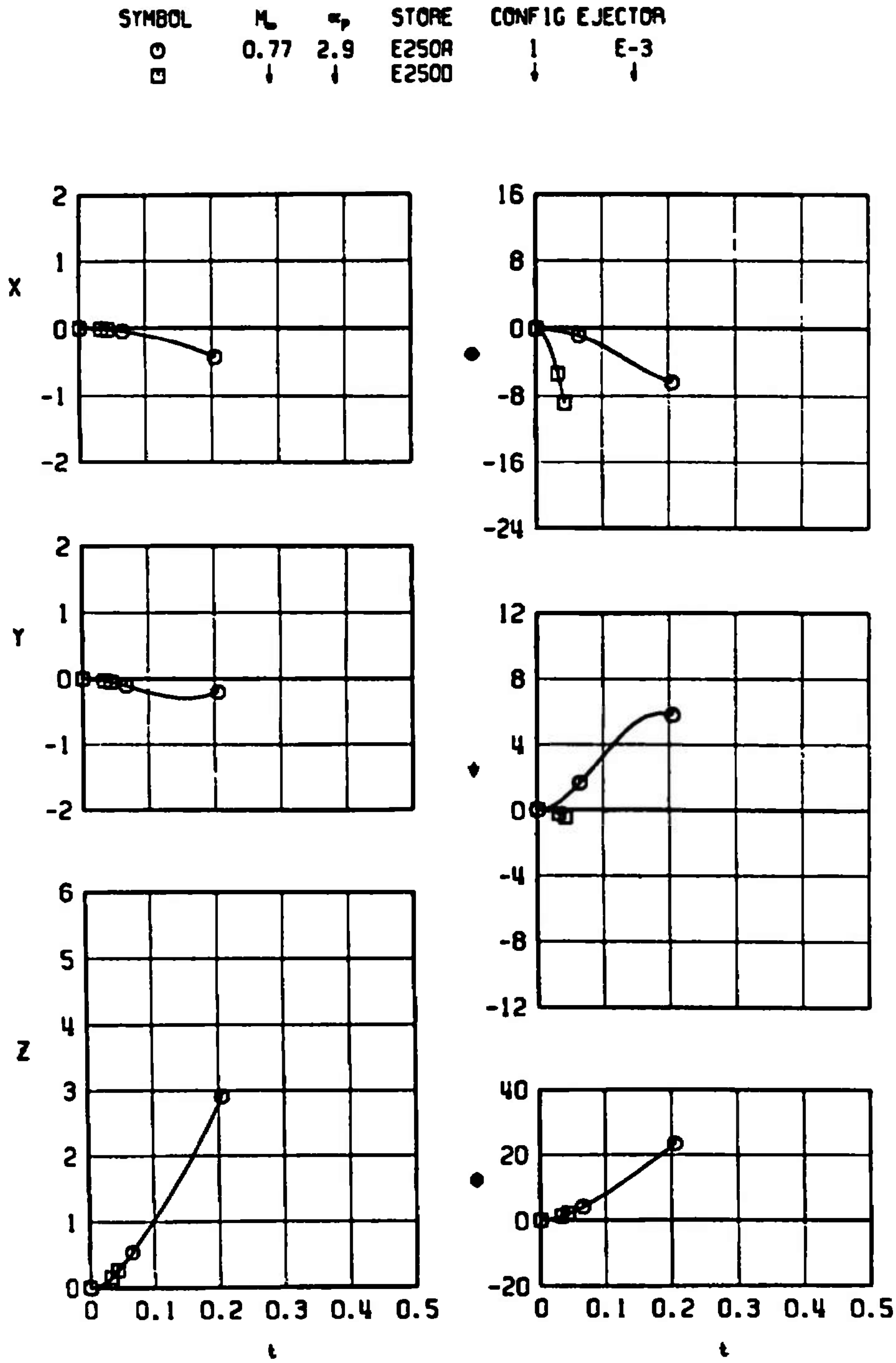
g. Configuration 2, M_∞ = 0.65, Ejector E-16
Fig. 15 Continued



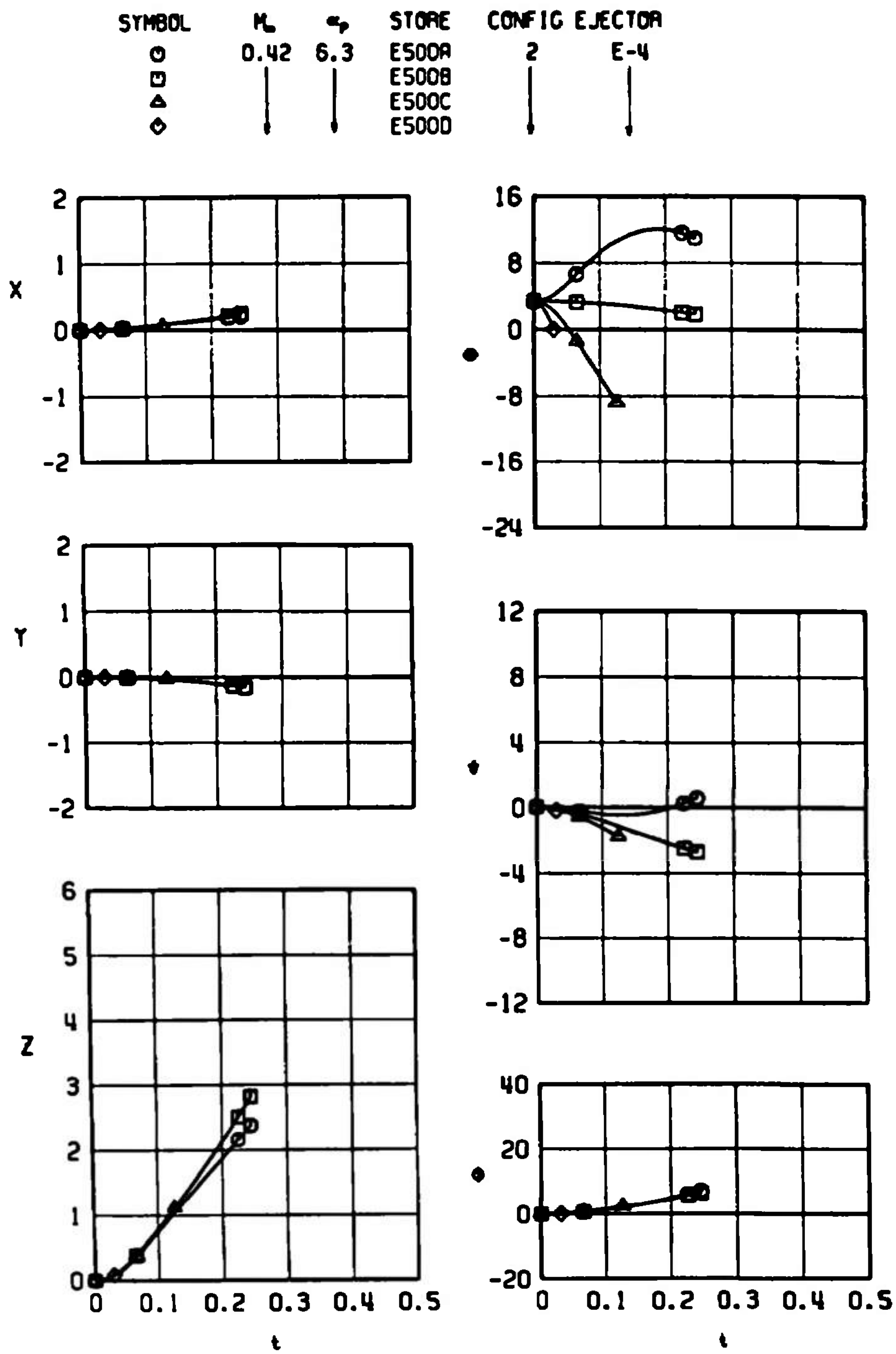
h. Configuration 2, M_{∞} = 0.77, Ejector E-3
Fig. 15 Continued



i. Configuration 2, M_∞ = 0.77, Ejector E-16
Fig. 15 Continued

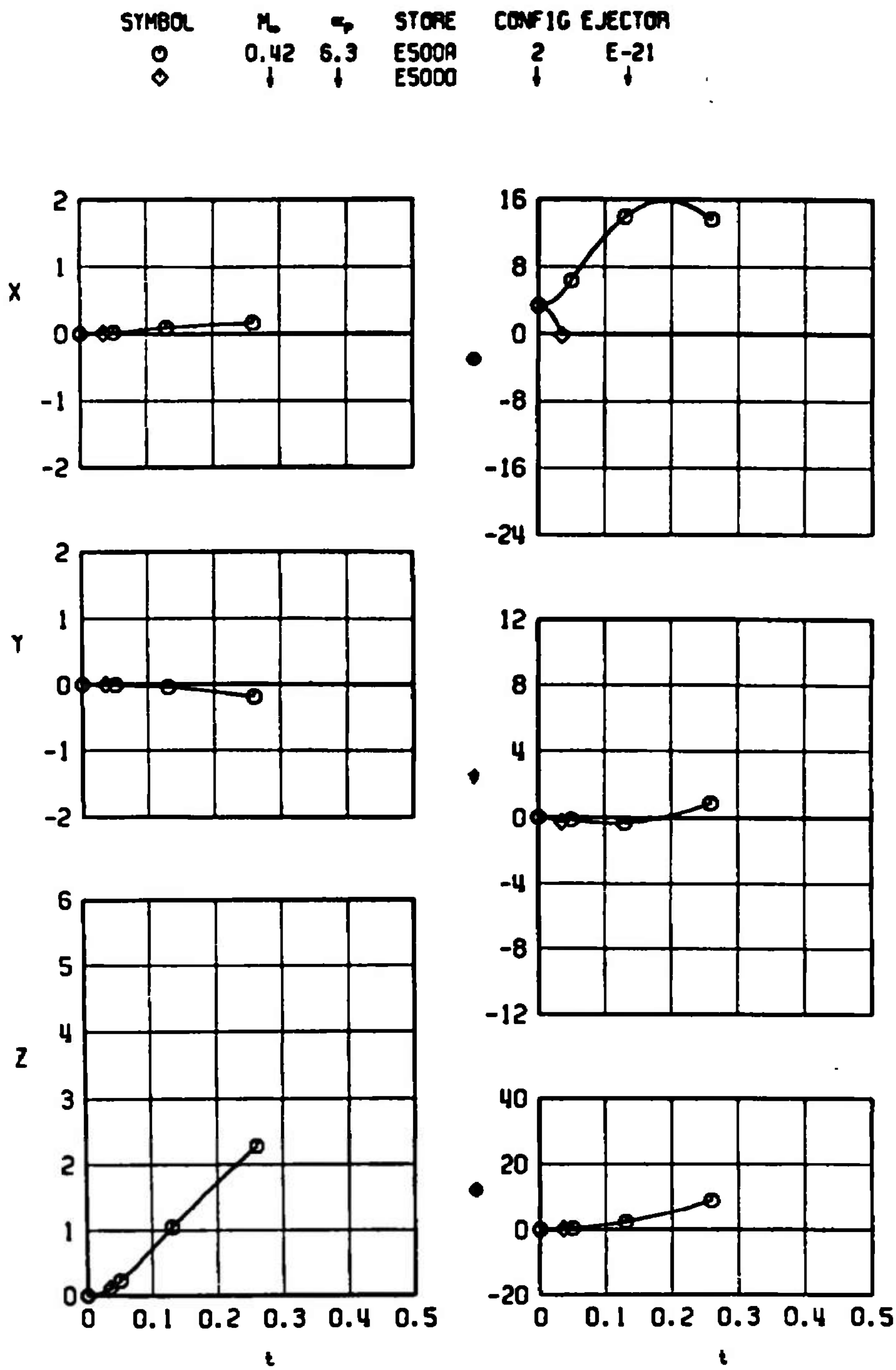


j. Configuration 1, M_∞ = 0.77, Ejector E-3
Fig. 15 Concluded

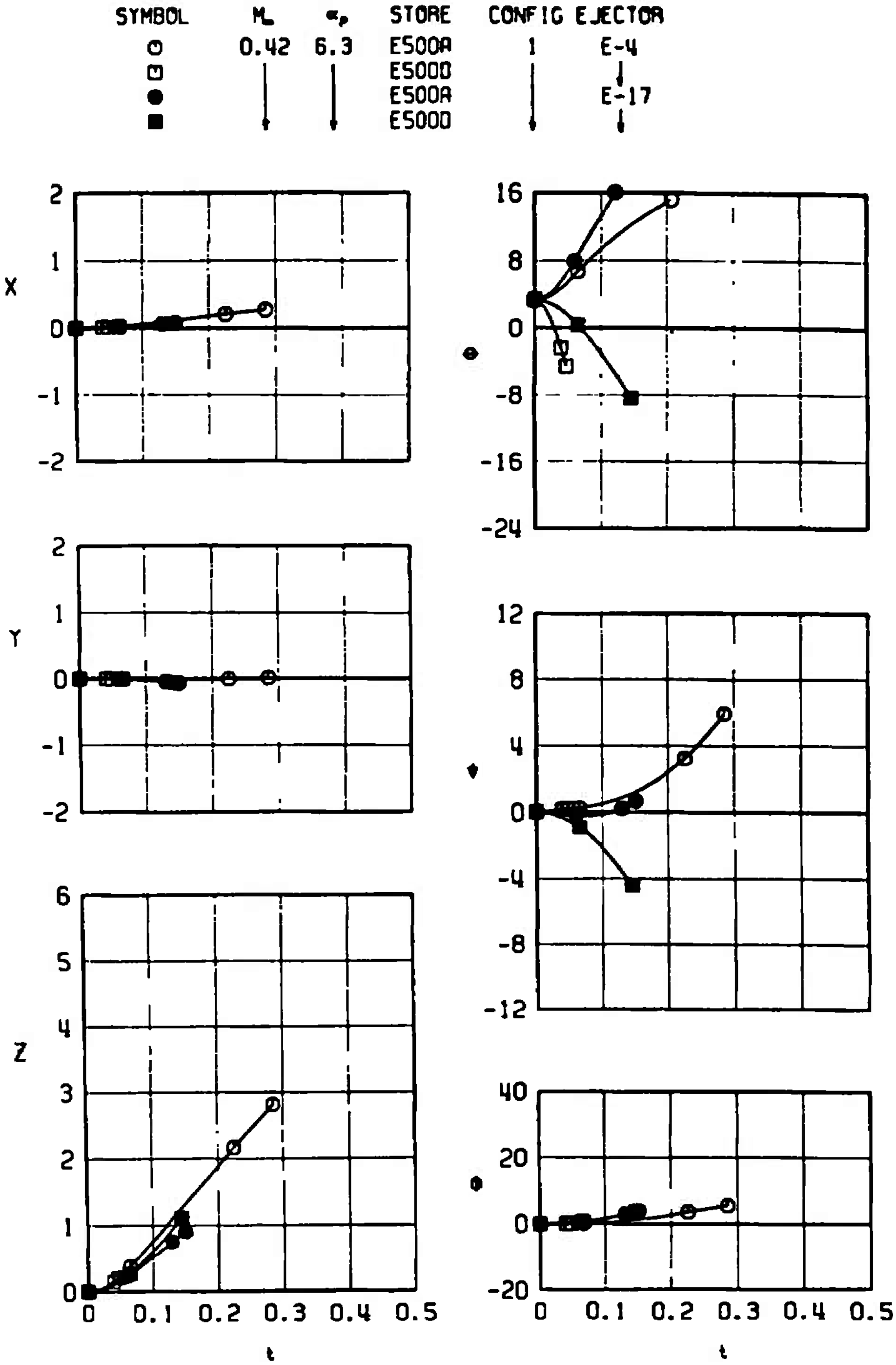


a. Configuration 2, M_∞ = 0.42, Ejector E-4

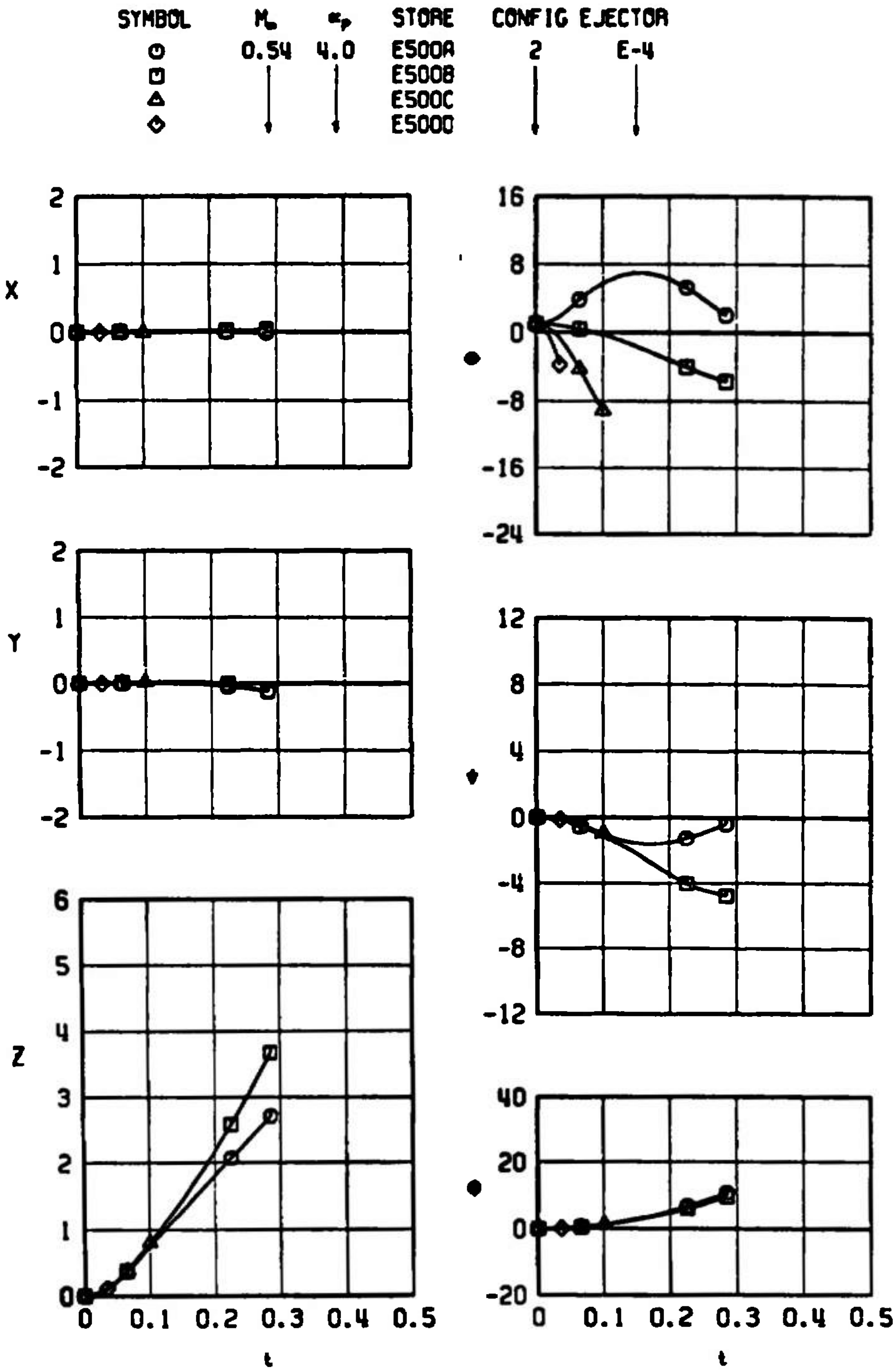
Fig. 16 Effects of Store cg Location on the CTU-1/A "E500" Series Launch Trajectories for Different Mach Numbers and Ejector Forces



b. Configuration 2, M_∞ = 0.42, Ejector E-21
Fig. 16 Continued

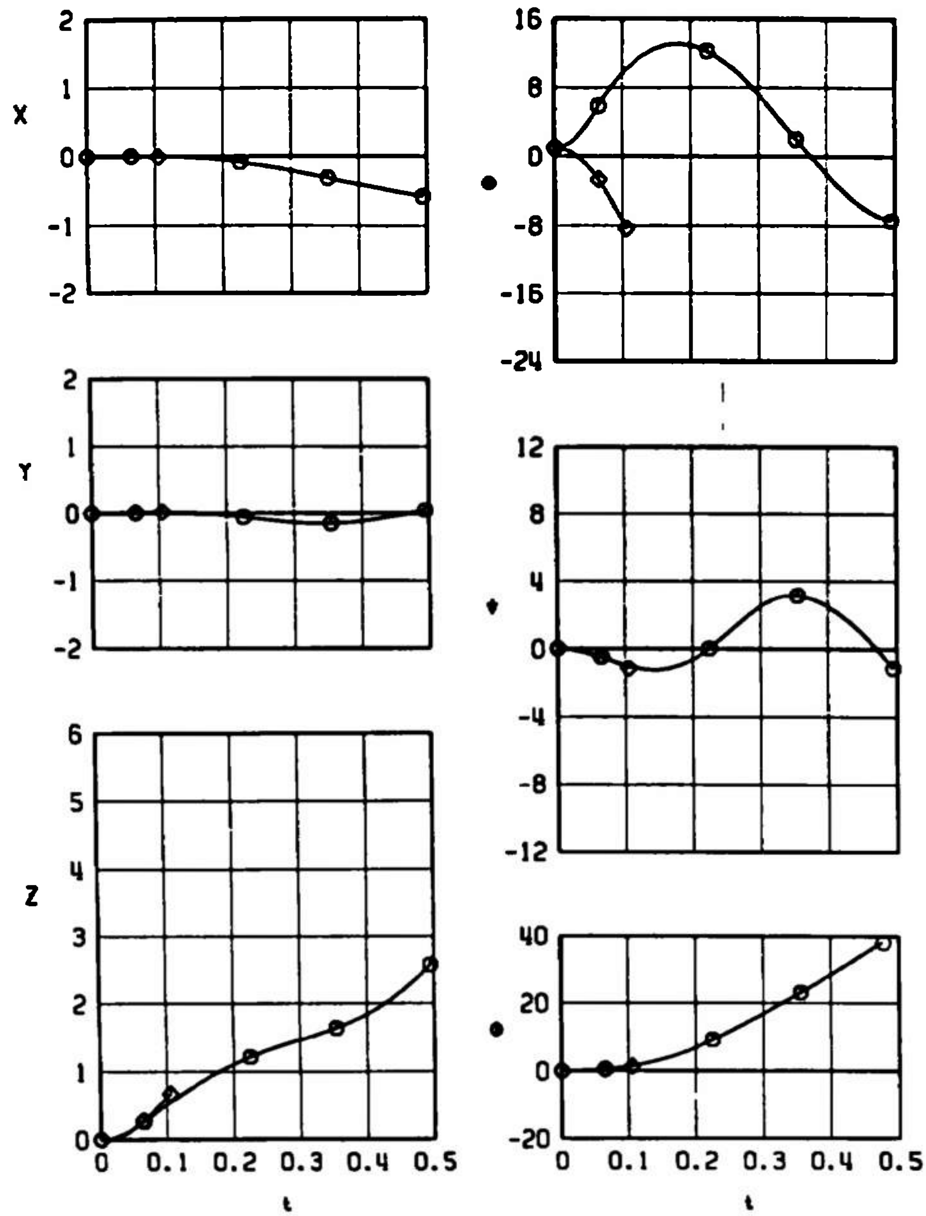


c. Configuration 1, M_∞ = 0.42, Ejectors E-4 and E-17
Fig. 16 Continued

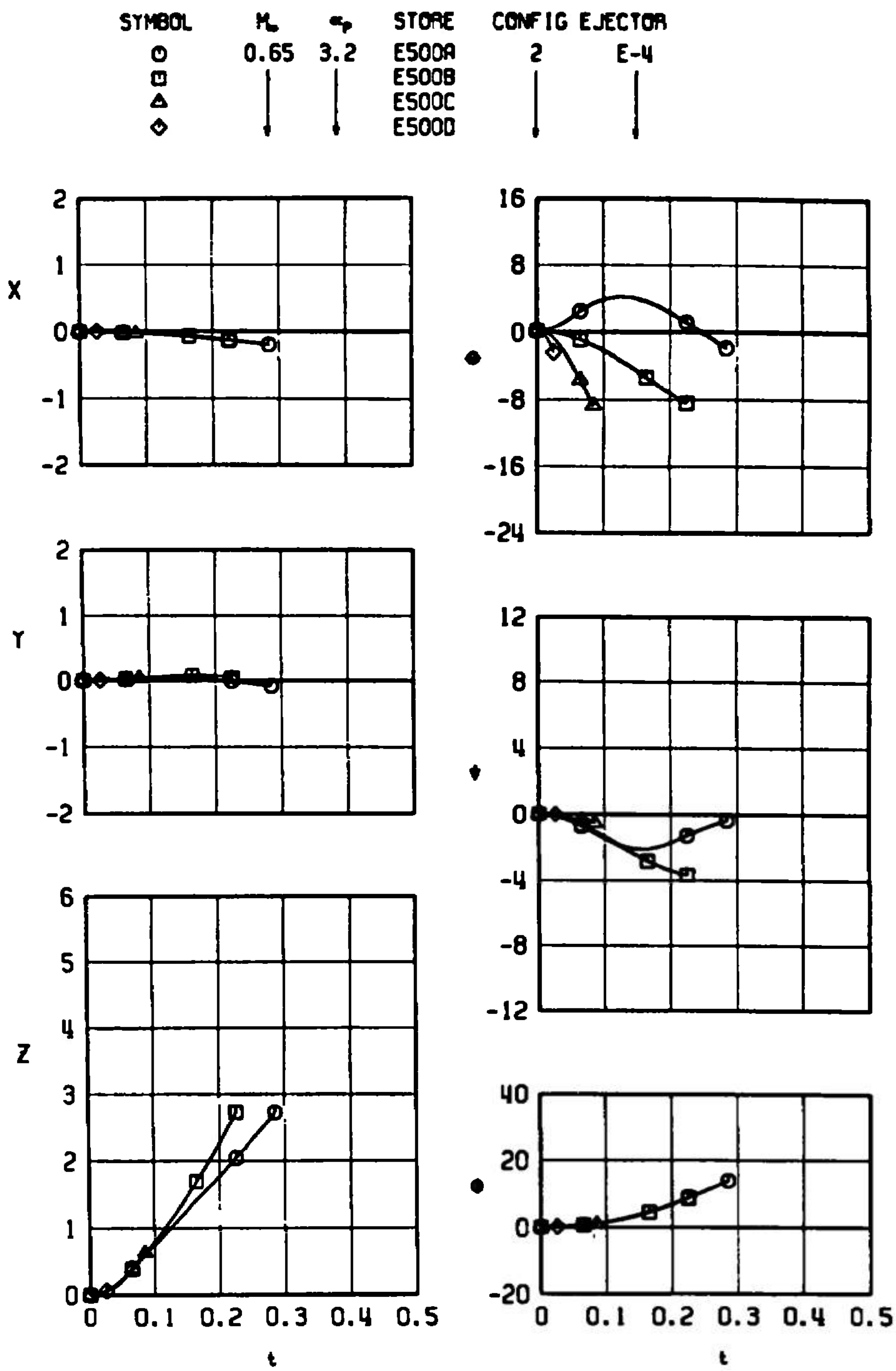


d. Configuration 2, M_∞ = 0.54, Ejector E-4
Fig. 16 Continued

SYMBOL	M_∞	α_p	STORE	CONFIG	EJECTOR
○	0.54	4.0	E500A	2	E-17
◇	↓	↓	E500D	↓	↓

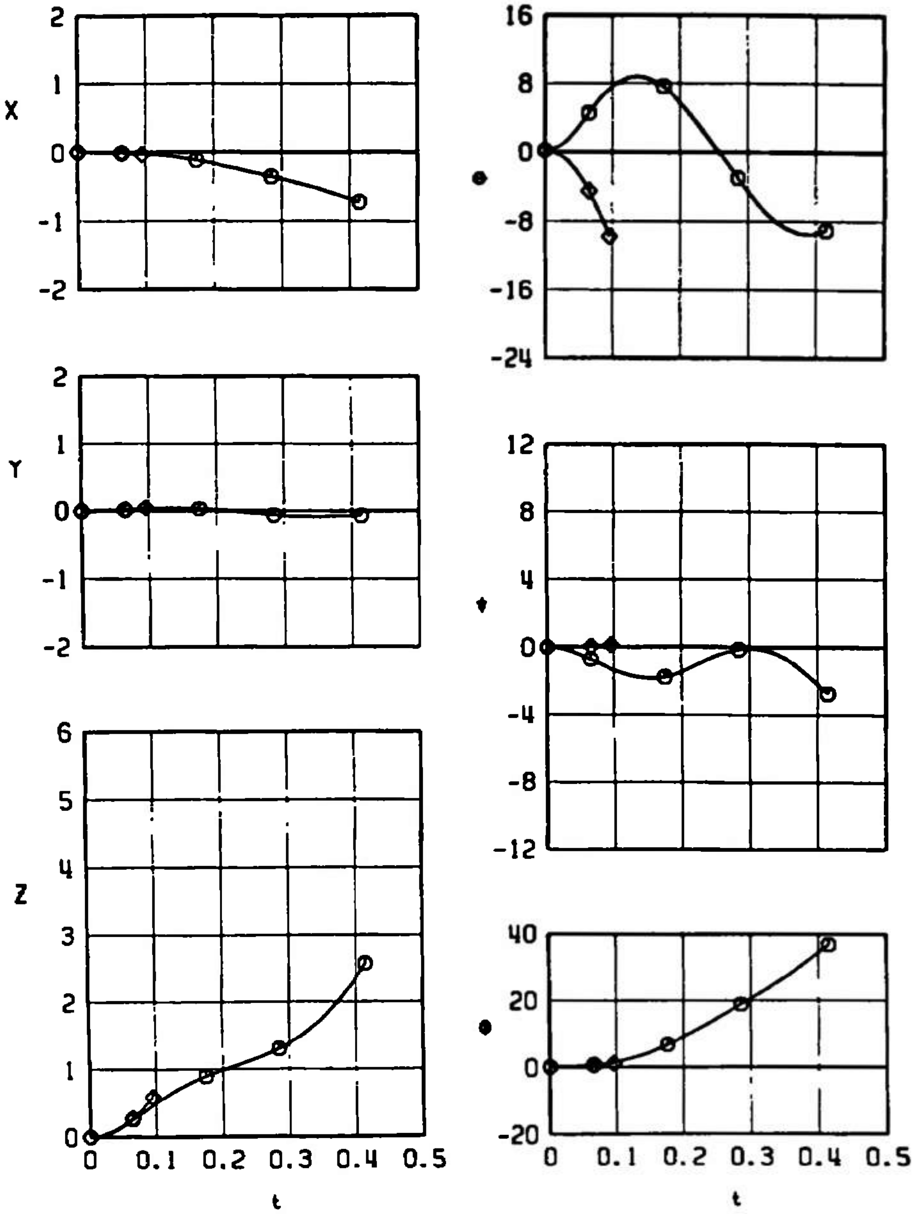


e. Configuration 2, M_∞ = 0.54, Ejector E-17
Fig. 16 Continued

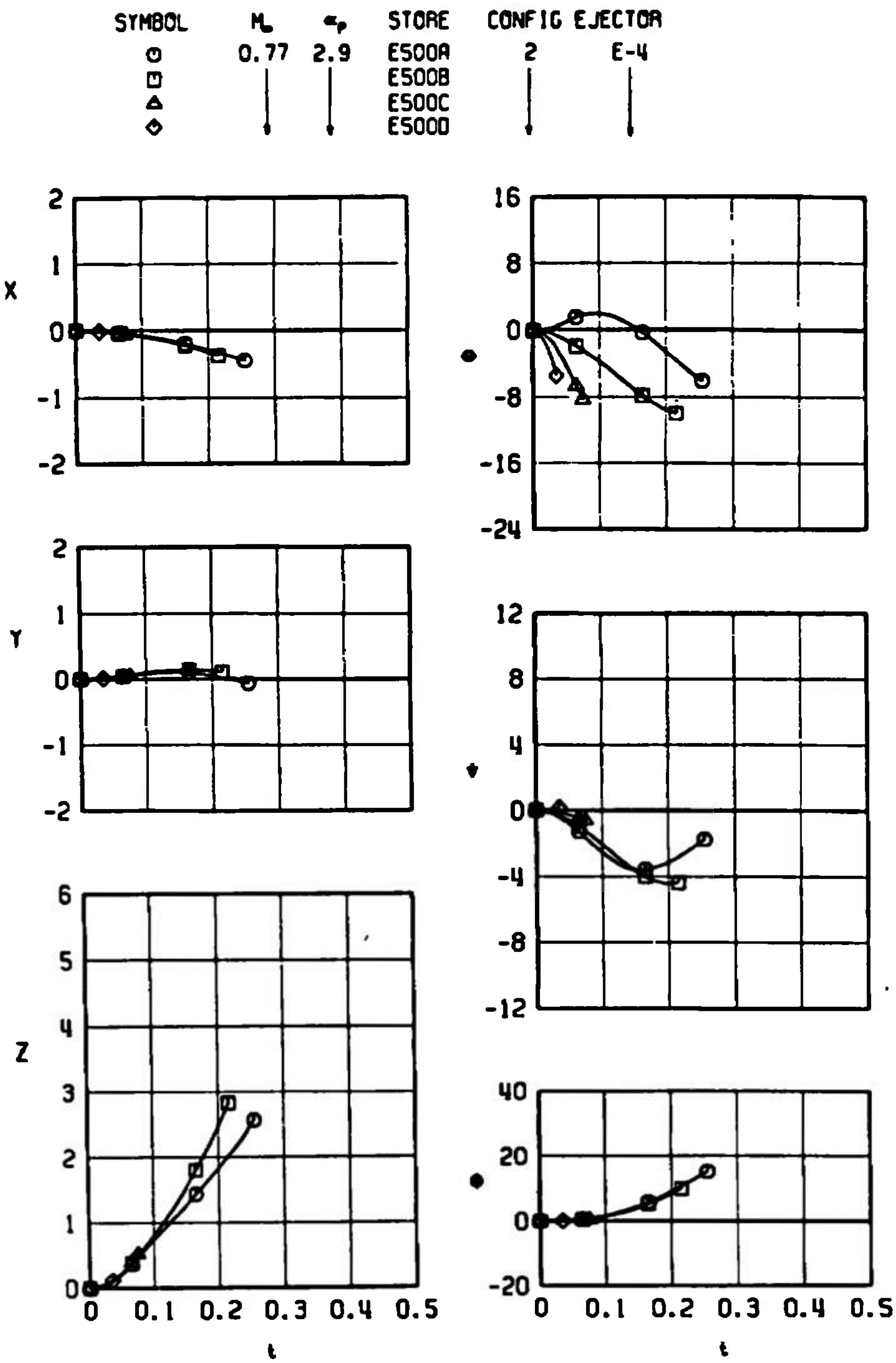


f. Configuration 2, M_∞ = 0.65, Ejector E-4
Fig. 16 Continued

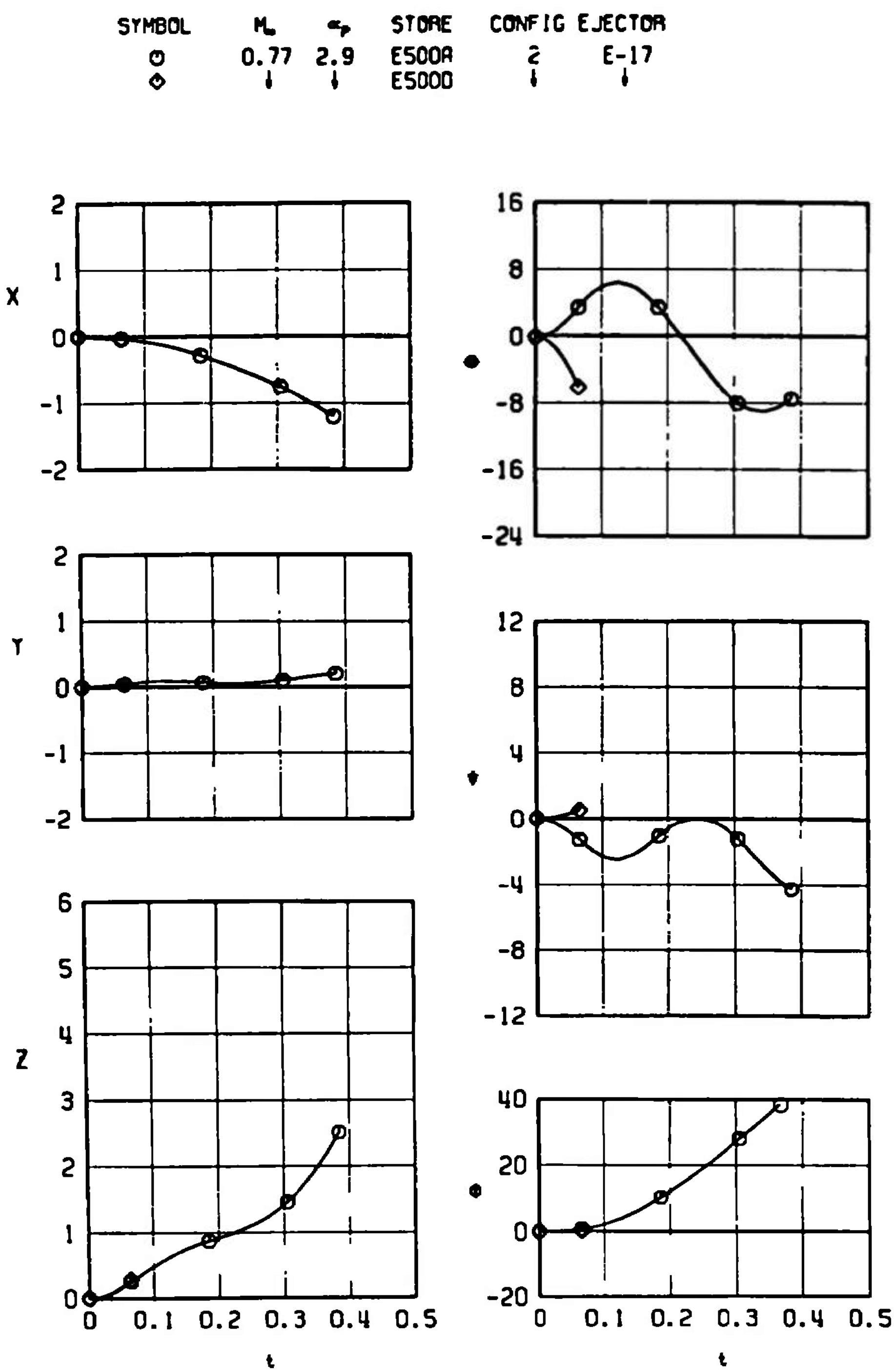
SYMBOL	M_∞	α_p	STORE	CONFIG	EJECTOR
○	0.65	3.2	E500A	2	E-17
◇	↓	↓	E500D	↓	↓



g. Configuration 2, M_∞ = 0.65, Ejector E-17
Fig. 16 Continued

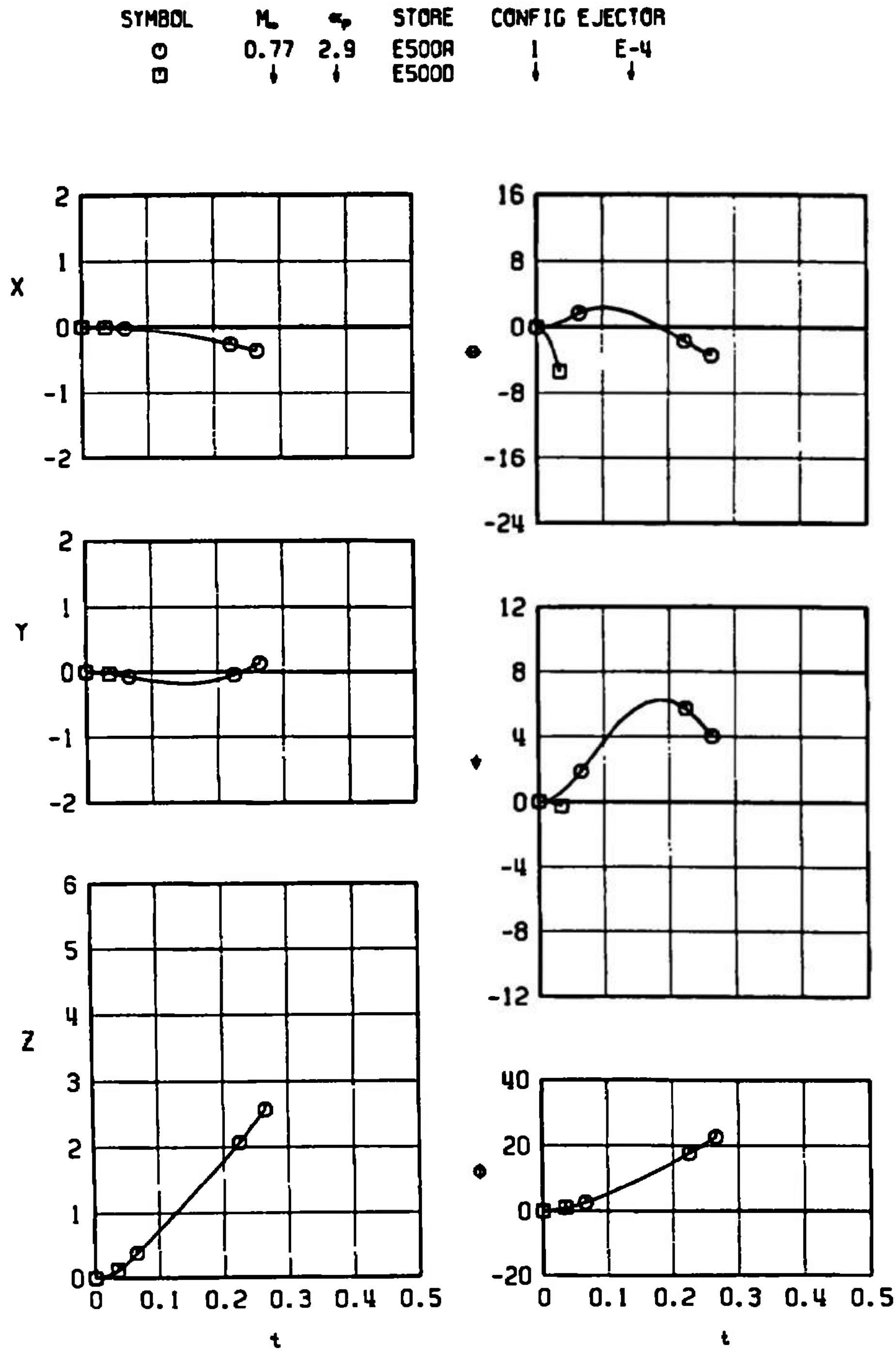


h. Configuration 2, M_∞ = 0.77, Ejector E-4
Fig. 16 Continued



i. Configuration 2, M_∞ = 0.77, Ejector E-17

Fig. 16 Continued



j. Configuration 1, M_∞ = 0.77, Ejector E-4
Fig. 16 Concluded

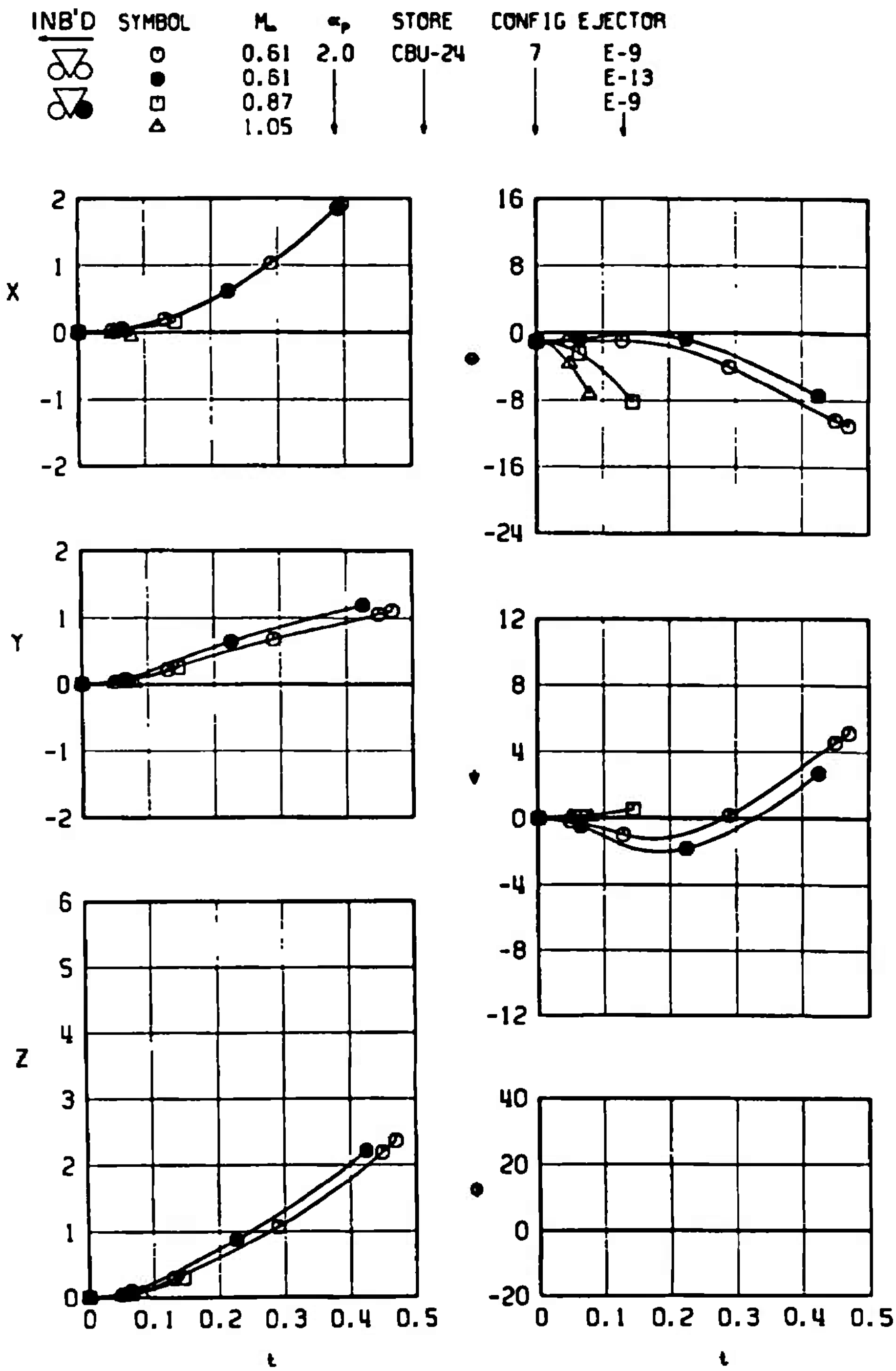
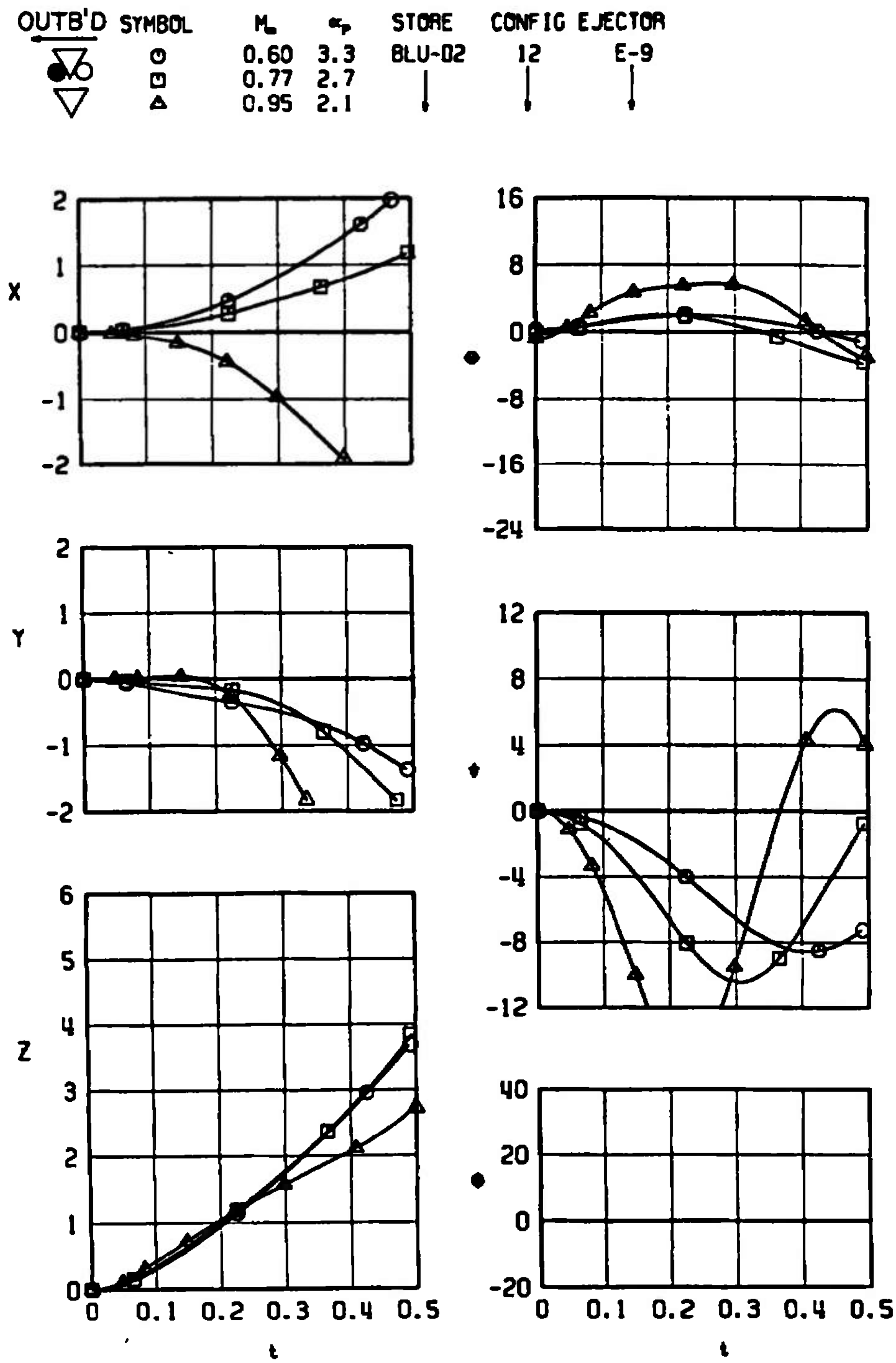
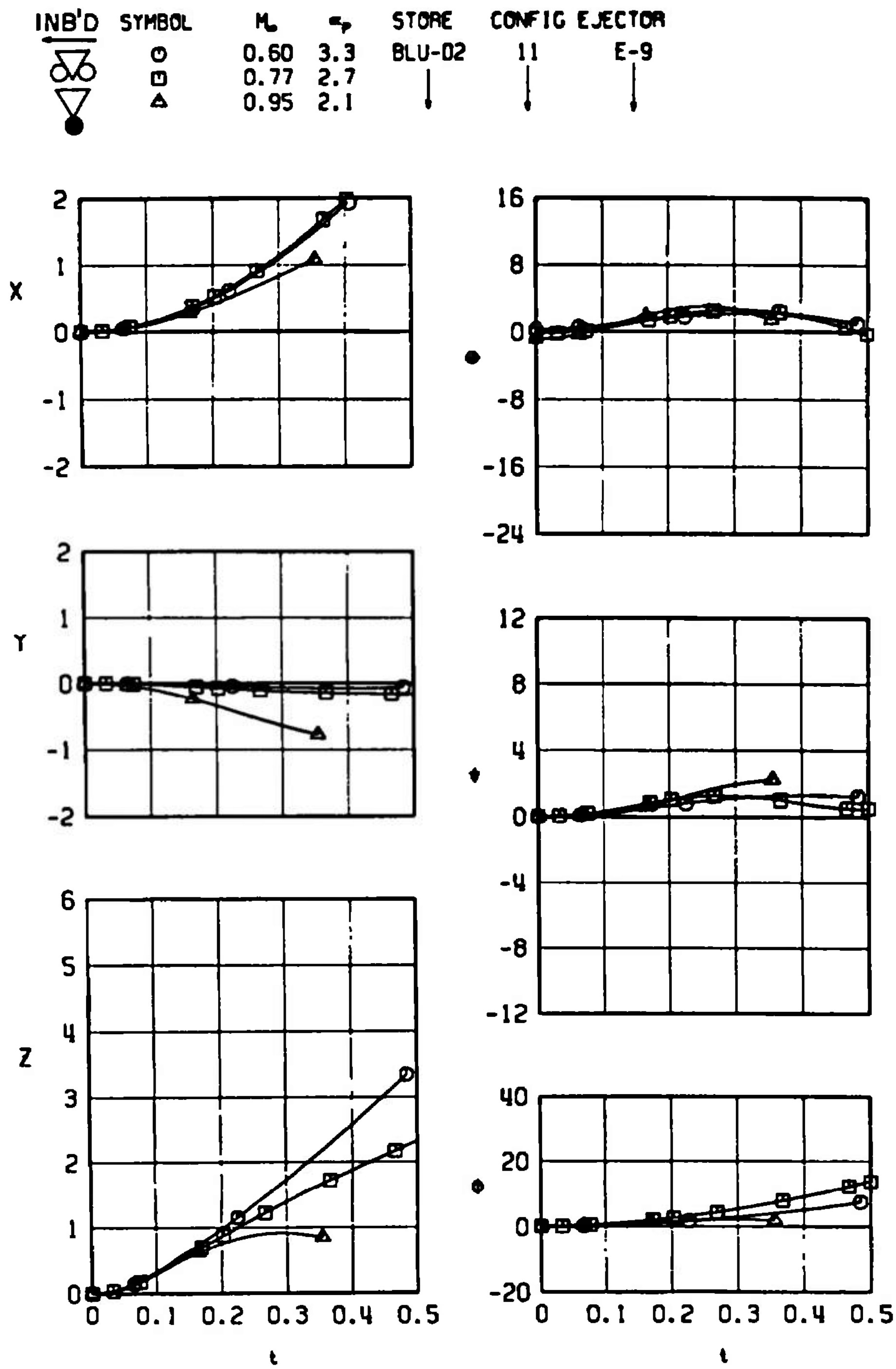


Fig. 17 Mach Number Comparison of the CBU-24B/B Launch Trajectories

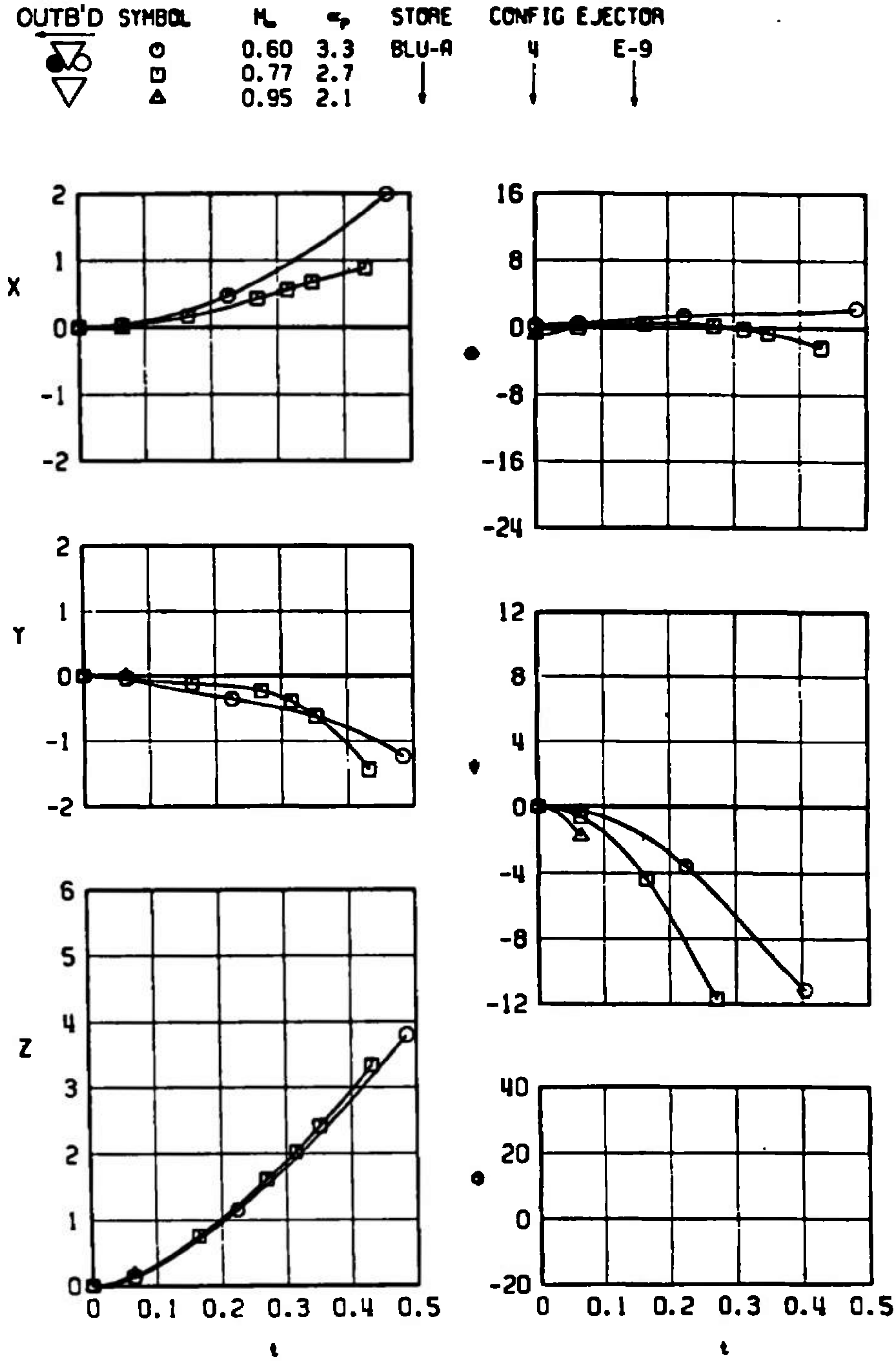


a. Tail D2, Configuration 12

Fig. 18 Mach Number Comparison of the Finned BLU-1C/B Launch Trajectories for Different Tail Fins and Launch Positions

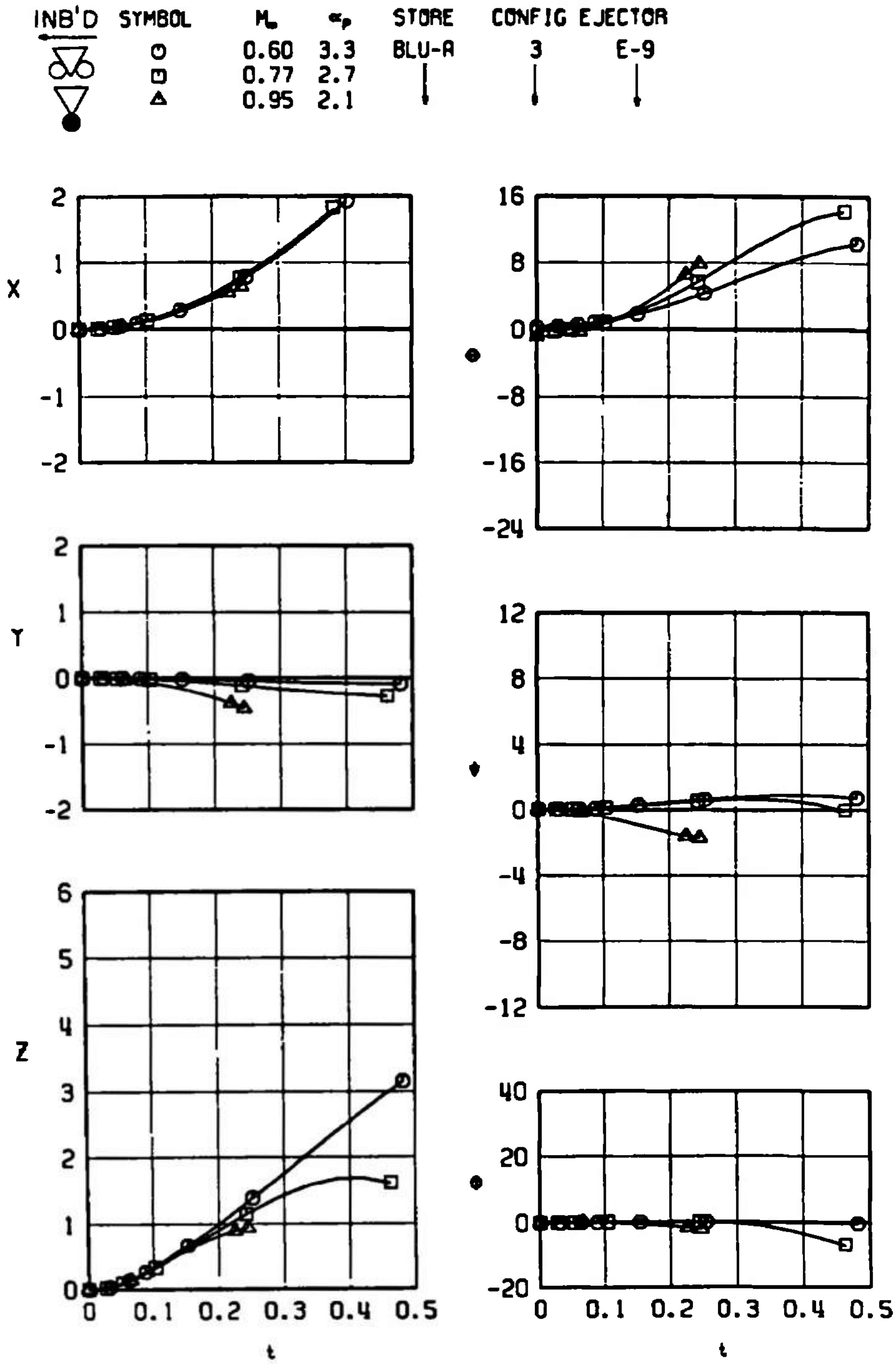


b. Tail D2, Configuration 11
Fig. 18 Continued

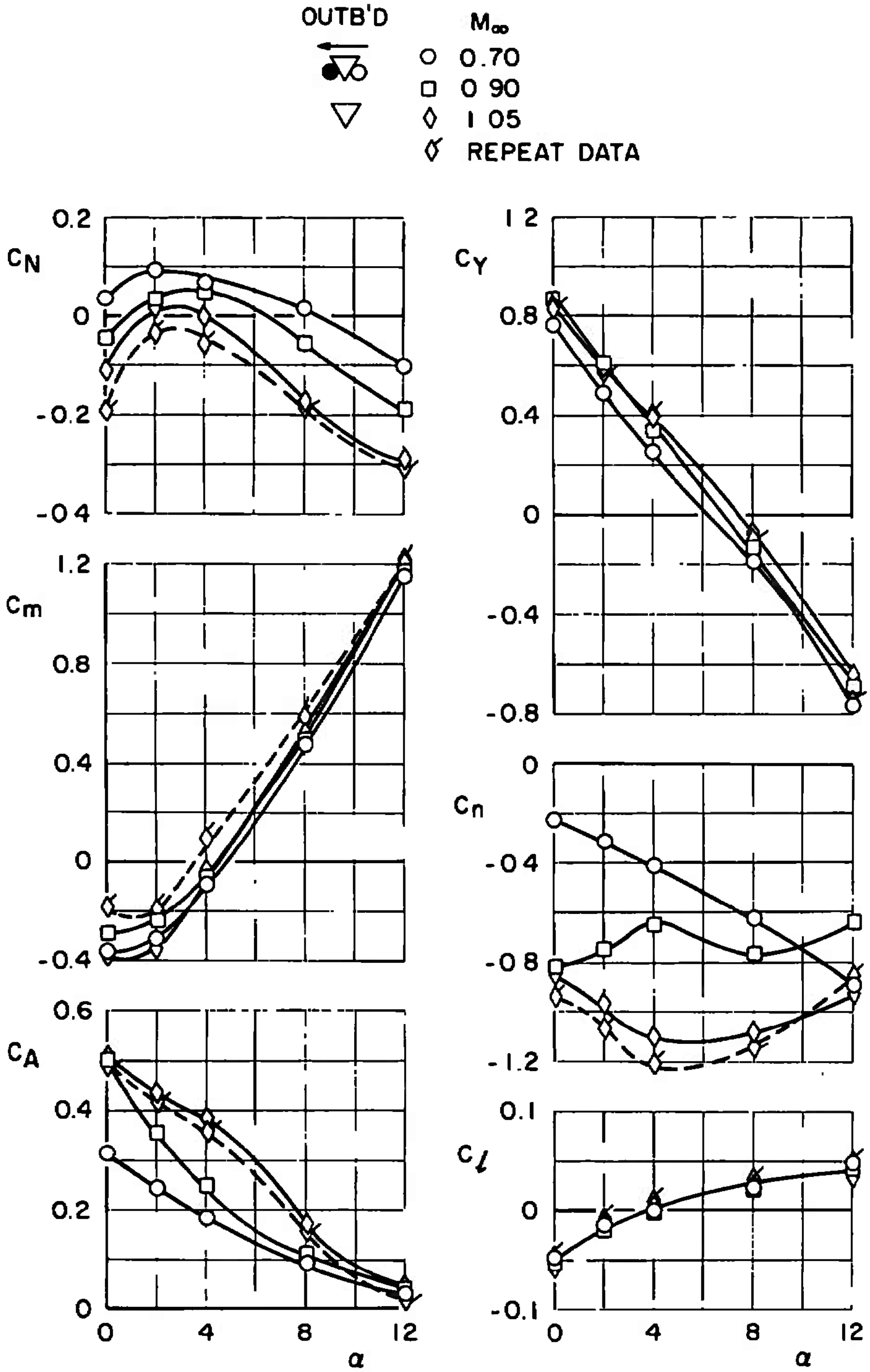


c. Tail A, Configuration 4

Fig. 18 Continued

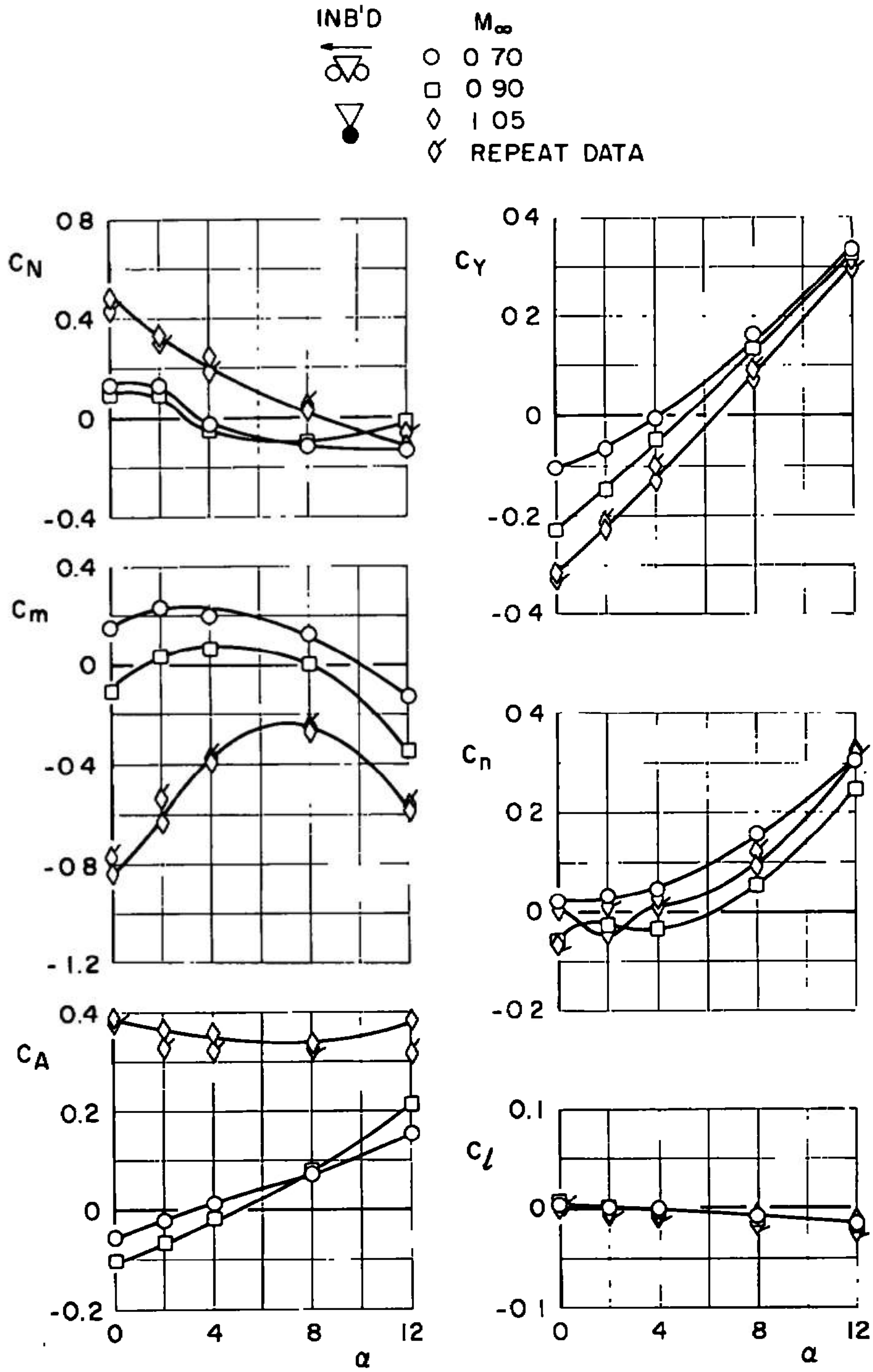


d. Tail A, Configuration 3
Fig. 18 Concluded



a. Configuration 4

Fig. 19 Variation of the Aerodynamic Coefficients of the Finned BLU-1C/B Store (Tail A) with Parent-Aircraft Angle of Attack Prior to Launch for Different Mach Numbers



b. Configuration 3
Fig. 19 Concluded

TABLE I
FULL-SCALE STORE PARAMETERS USED IN TRAJECTORY CALCULATIONS

SYM	Parameter	Store														
		CTU-1/A												BLU-1 C/B		CBU-24B/B
		E	E50A	E50B	E50C	E50D	E250A	E250B	E250C	E250D	E500A	E500B	E500C	E500D	Tail A	Tail D2	
S	Store reference area, sq ft	2.405	2.405	2.405	2.405	2.405	2.405	2.405	2.405	2.405	2.405	2.405	2.405	2.405	1.887	1.887	1.396
b	Store reference width, ft	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.550	1.550	1.333
I_{xx}	Moment of inertia, slug-sq ft	2.8	3.2	3.2	3.2	3.2	5.5	5.5	5.5	5.5	8.5	8.5	8.5	0.5	10.0	10.0	5.0
I_{yy}	Moment of inertia, slug-sq ft	30.0	41.4	37.2	33.7	30.9	65.7	54.9	45.8	34.3	78.9	69.8	59.2	38.6	146.0	146.0	65.0
I_{zz}	Moment of inertia, slug-sq ft	30.0	41.4	37.2	33.7	30.9	65.7	54.9	45.8	34.3	78.9	69.8	59.2	38.6	146.0	146.0	65.0
C_{m_q}	Pitch-damping derivative, per rad	-26	-28	-27	-26	-26	-42	-33	-28	26	-52	-38	-29	-26	-48	-48	-54
C_{n_r}	Yaw-damping derivative, per rad	-26	-28	-27	-26	-26	42	-33	28	-26	-52	-38	29	-26	-48	-48	54
C_{ℓ_p}	Roll-damping derivative, per rad	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	5.0	-5.0	-5.0	-5.0	-5.0	-3.0	-3.0	-1.9
X_{cg}	Center-of-gravity location from nose, ft	5.708	5.150	5.333	5.525	5.708	4.100	4.625	5.167	5.708	3.817	4.308	5.000	5.708	5.458	5.458	3.217
m	Mass, slug	6.682	8.236	8.236	8.236	8.236	14.453	14.453	14.453	14.453	22.223	22.223	22.223	22.223	23.155	23.155	27.040
X_{L_1}	Forward ejection piston location, ft	2.042	1.483	1.667	1.050	2.042	0.433	0.958	1.500	2.042	-0.050	0.642	1.333	2.042	-0.092	-0.092	-0.375
X_{L_2}	Aft ejection piston location, ft	0.375	-0.183	0	0.192	0.375	1.233	-0.708	-0.167	0.375	-1.717	-1.025	-0.333	0.375	---		---
γ	Dive angle, deg	15	15	15	15	15	15	15	15	15	15	15	15	15	50	50	70
H	Pressure altitude, ft	500	500	500	500	500	500	500	500	500	500	500	500	500	7000	7000	8000
	Ejector stroke length, ft	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.342	0.242	0.242	0.242
F_{z_1} F_{z_2}	Forward and aft ejector forces, lb (see ejector force table)	E-1 E-14 E-18	E-2 E-15 E-19	E-2 E-15	E-2 E-15	E-2 E-15 E-19	E-3 E-16 E-20	E-3	E-3	E-3 E-16 E-20	E-4 E-17 E-21	E-4	E-4	E-4 E-17 E-21	E-9	E-9	E-9 E-13

Ejector Forces

Code	F_{z_1}, lb	F_{z_2}, lb	Code	F_{z_1}, lb	F_{z_2}, lb
E-1	2000	1120	E-15	---	2310
E-2	2070	1150	E-16	---	2340
E-3	2140	1340	E-17	---	2250
E-4	2070	1410	E-18	1120	2000
E-9	1150	---	E-19	1150	2070
E-13	1600	---	E-20	1340	2140
E-14	---	2100	E-21	1410	2070

TABLE II
A-7D LOAD CONFIGURATION

Config No	Left Wing Pylon			Config No	Right Wing Pylon		
	Outboard	Center	Inboard		Inboard	Center	Outboard
2	CTU-1/A	Empty	Empty	1	300-gal Fuel Tank	LAU-3/A Full	CTU-1/A
4	Empty	BLU-1C/B (Tail A)		3	Empty	BLU-1C/B (Tail A)	Empty
12		BLU-1C/B (Tail D2)		11		BLU-1C/B (Tail D2)	
8		CBU-24B/B		7		CBU-24B/B	

Note: Solid denotes launched store

Open denotes dummy store

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) Arnold Engineering Development Center Arnold Air Force Station, Tennessee 37389	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP N/A

3 REPORT TITLE

SEPARATION CHARACTERISTICS OF THE CTU-1/A, FINNED BLU-1C/B, AND CBU-24B/B STORES FROM THE A-7D AIRCRAFT AT MACH NUMBERS 0.42 TO 1.05

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report - July 25 and 26, 1973

5 AUTHOR(S) (First name, middle initial, last name)

J. B. Carman, Jr., ARO, Inc.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
October 1973	72	2

8a. CONTRACT OR GRANT NO. b. PROJECT NO. c. Program Element 27121F d. System 337A	9a. ORIGINATOR'S REPORT NUMBER(S) AEDC-TR-73-174 AFATL-TR-73-207 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) ARO-PWT-TR-73-115

10 DISTRIBUTION STATEMENT ~~Distribution limited to U.S. Government agencies only; this report contains information on test and evaluation of military hardware; October 1973; other requests for this document must be referred to Air Force Armament Laboratory (DLJA), Eglin AFB, Florida 32542.~~

11 SUPPLEMENTARY NOTES Available in DDC	12. SPONSORING MILITARY ACTIVITY AFATL/DLJA Eglin AFB, Florida 32542

13 ABSTRACT

Wind tunnel tests were conducted using 0.05-scale models to study the separation characteristics of the CTU-1/A, finned BLU-1C/B, and CBU-24B/B stores from the A-7D aircraft. Separation trajectories of the CTU-1/A store were initiated from the left and right wing outboard pylons while separation trajectories of the finned BLU-1C/B and CBU-24B/B munitions were initiated from a multiple ejection rack on the left and right wing center pylons. Data were obtained at Mach numbers 0.42 to 1.05 at simulated altitudes of 500 to 8000 ft. Other simulated flight variables included store weight and center-of-gravity position, dive angle, and ejector force.

This document has been approved for public release its distribution is unlimited. Per TAB 76-3, Dtd 30 Jan., 1976

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
external stores						
trajectories						
separation						
scale models						
Mach number						
angle of attack						

AFSC
Arnold AFS Tenn

UNCLASSIFIED
Security Classification